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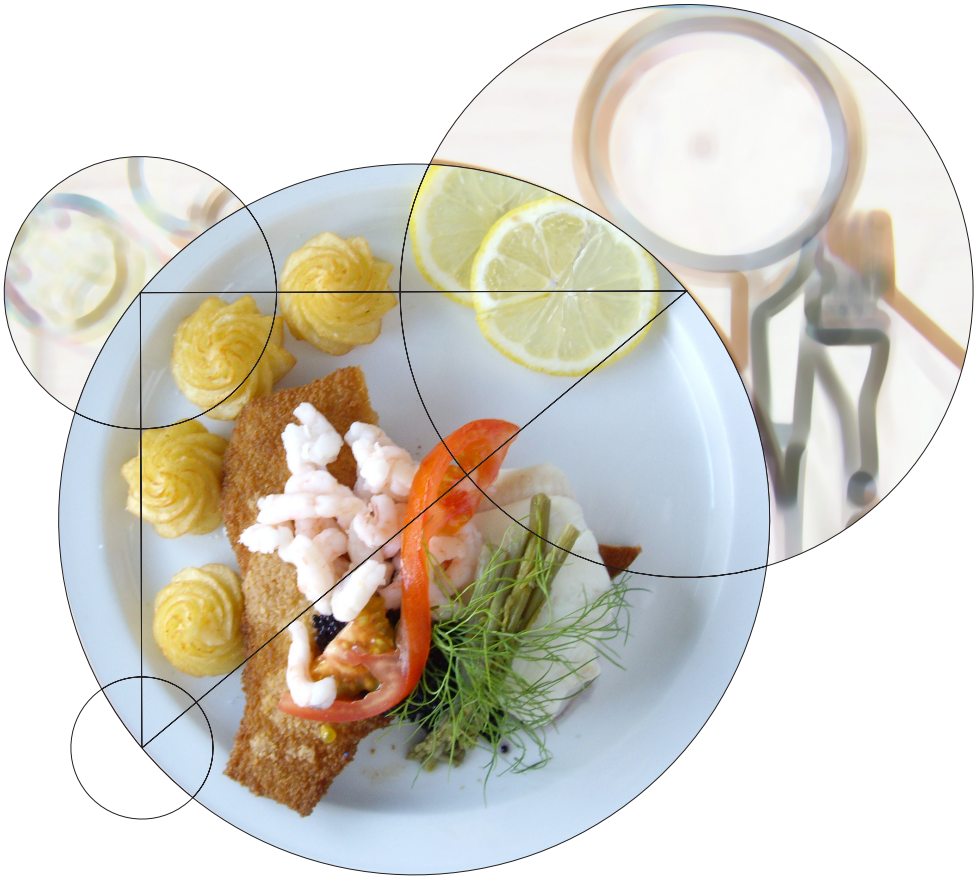
PhD thesis · 2011

Janice Marie Sorensen



Framework for developing functional foods for patients at nutritional risk

PhD thesis by

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May 2010

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Framework for developing functional foods for patients at nutritional risk

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Preface

The PhD project presented in this thesis was conducted at the Department of Human Nutrition, Faculty of Life Sciences, University of Copenhagen and supported in part by Arla Foods, the Danish Dairy Research Foundation and a scholarship from the Faculty of Life Sciences, University of Copenhagen. The research work was carried out at the Copenhagen University Hospital (Rigshospitalet) at the departments of gastrointestinal surgery, infectious medicine, cardiology, hepatology, oncology, haematology and rheumatology and in collaboration with the Central Kitchen and based at the Nutrition Unit.

The PhD thesis includes the following three original papers, which will be referred to as:

Paper I. Janice Sorensen, Lotte Holm, Michael Bom Frøst, and Jens Kondrup. Food for patients at nutritional risk: a model of food sensory quality to promote intake. *(submitted to Clinical Nutrition)*

Paper II. Janice Sorensen, Michael Bom Frøst, Lotte Holm, and Jens Kondrup. Food sensory needs of patients at nutritional risk: a questionnaire study. *(in preparation)*

Paper III. Janice Sorensen and Jens Kondrup. Effect of food-sensory-based nutritional care on intake, physiological function and quality of life: a randomised, assessor-blinded controlled trial in hospitalised patients at nutritional risk. *(in preparation)*

The PhD project has also involved food sensory analysis studies, which are mentioned briefly in the methods section 3.2 on project and study design, but are not a focus of this thesis.

Acknowledgments

Throughout this project, I have received invaluable assistance and support from many individuals. I would like to express my sincere gratitude to everyone that contributed to this project and would especially like to thank:

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- This work is in loving memory of my father, **Leslie Sorensen**, from whom I have learned so many life lessons and gained a more personal understanding of this topic.

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Abstract

Background & Aims

Hospital undernutrition is a common problem associated with decreased physiological function, diminished quality of life, and poor clinical outcome in patients. Lack of appetite and unsuitability of the hospital food have been previously identified as contributing factors to insufficient food intake in patients at nutritional risk. Food sensory quality, as perceived by geriatric patients, has been found to be positively associated with food intake. The current project aimed to establish a framework for developing functional foods, i.e., appetising, energy- and protein-rich foods, to promote intake in patients at nutritional risk, and thereby, improve outcome.

Methods

Studies were done in hospital patients at nutritional risk (NRS-2002) from gastrointestinal surgery, oncology, infectious medicine, cardiology, rheumatology, hepatology, and haematology departments.

Study I: A qualitative study was conducted to investigate food sensory quality as perceived by patients at nutritional risk based on direct meal observations (food choice, hunger/fullness/appetite scores), 3-day food records post-discharge, and multiple semi-structured interviews on patients' meals experiences in hospital and two weeks post-discharge. Interviews were transcribed, coded, and analysed thematically.

Study II: The results of the qualitative study formed the basis for a patient food choice questionnaire about eating-related symptoms (15 three-point scale questions) and food sensory needs and motivation to eat (46 Likert scale questions). Prevalence of the factors investigated and associations with food intake were assessed in a larger, heterogeneous group of patients at nutritional risk. Principal component analysis (PCA) was used to examine patterns of association between variables.

Study III: A randomised controlled trial was conducted in medical patients at nutritional risk, who were randomised to individualised, food-sensory-quality-based nutritional care (intervention) or usual care and nutritional advice (control). The intervention was based on the results from the qualitative study and used the patient food choice questionnaire. Food intake was recorded daily and change in handgrip strength, reaction time, weight, and bioelectrical impedance were assessed every 3-4 days (assessor-blinded), and quality of life (SF-36 questionnaire) after 28 days (assessor blinded).

Results

Study I: Patients (N=22) in the qualitative study participated in 65 interviews. Food sensory perception and eating ability dictated the individual food sensory needs of patients at nutritional risk (i.e., appearance, aroma, taste, texture, temperature and variety defining food sensory quality to promote intake) within the context of motivation to eat identified as: pleasure, comfort, and survival. These observations provided the basis for a model of food sensory quality to promote intake.

Study II: PCA of the questionnaire study results (N=200) segmented patients by their motivation to eat: pleasure *vs.* survival, which corresponded to contrasting food sensory needs: awakening appetite *vs.* facilitating intake, respectively. Energy and/or protein balance was positively associated with enjoying eating, preference for different tastes, sour side dishes, and sour, savoury, and pleasantly satiating foods and negatively associated with forced eating, low appetite, early satiety, stomach pain, nausea, taste changes, swallowing problems, nauseating aromas, difficulty forming a bolus, and preference for 'light foods', familiar foods, and foods tasting as preferred.

Study III: The intervention group (N=42) had higher energy balance (111% *vs.* 93%, $p = 0.009$) and protein balance (96% *vs.* 82%, $p = 0.016$) than the control group (N=39). Energy balance was ≥75% in 90% *vs.* 70% ($p = 0.029$) and protein balance was ≥75% for 83% *vs.* 57% ($p = 0.028$) of intervention *vs.* control patients, respectively. The intervention *vs.* control group had improved handgrip strength after 3-5 days (mean 3.0 kg *vs.* 2.7 kg) and reaction time after 9-11 days (median -86 ms *vs.* -49 ms), which was positively associated with intake, but did not differ between groups.

Conclusions

A framework of food sensory quality to promote intake in patients at nutritional risk was developed. Application of this framework in individualised, food-sensory-quality-based nutritional care improved energy and protein intake in hospital patients at nutritional risk compared to usual nutritional care. Physiological function improved within a few days of food-based nutritional care. Further studies are needed to determine whether application of the framework in the development of user-driven, innovative food and beverages can demonstrate an increase in food intake in patients at nutritional risk.

Dansk Resumé

Baggrund & formål

Underernæring på hospitaler er hyppigt forekommende og er associeret med nedsat fysiologisk funktion, forringet livskvalitet, og et dårligere klinisk forløb. Manglende appetit og uegnet hospitalsmad er tidligere identificeret som bidragende til det insufficiente kostindtag hos ernæringsrisikopatienter. Madens sensoriske kvaliteter har vist sig at være positivt associeret med kostindtag hos geriatriske patienter. Nærværende projekt havde til formål at fastsætte en model for udvikling af funktionelle fødevarer, dvs. appetitstimulerende, energi- og proteinrige fødevarer, som kan fremme kostindtaget hos ernæringsrisikopatienter og derved forbedre klinisk forløb.

Metoder

Studierne inkluderede hospitalsindlagte patienter i ernæringsrisiko (NRS-2002) fra gastrokirurgiske, onkologiske, infektionsmedicinske, kardiologiske, reumatologiske, hepatologiske, og hæmatologiske afdelinger.

Studie I: Der blev udført et kvalitativt studie for at undersøge ernæringsrisikopatienters opfattelse af madens sensoriske kvaliteter baseret på direkte observationer af måltider (valg af mad, sult/mæthed/appetit scoringer), 3-dags kostregistreringer efter udskrivelse og flere semi-strukturerede interviews omkring patienters måltidsoplevelser under hospitalsopholdet og to uger efter udskrivelse. Transskribering, kodning og systematiske analyser af interviewene blev foretaget.

Studie II: Resultaterne fra det kvalitative studie dannede basis for et spørgeskema om patienters madvalg, som omhandlende spise-relaterede symptomer (15 skalerede spørgsmål med tre svarkategorier), sensoriske behov og motivation for at spise (46 skalerede spørgsmål efter Likert). Forekomsten af de undersøgte faktorer og associationer med kostindtag blev vurderet i en større, heterogen gruppe af patienter i ernæringsrisiko. Der blev anvendt principal komponent analyse (PCA) til at undersøge sammenhænge mellem variabler.

Studie III: Der blev gennemført et randomiseret kontrolleret studie, som inkluderede medicinske patienter i ernæringsrisiko. Patienterne blev randomiseret til individualiseret, fødevaresensorisk-kvalitets-baseret ernæringsterapi (intervention) eller traditionel pleje og kostråd (kontrol). Interventionen var baseret på det kvalitative studie og anvendte spørgeskemaet om patienters madvalg. Kostindtag blev registreret dagligt og ændringer i håndgribestyrke, reaktionstid, vægt og bioelektrisk impedans blev målt hver 3-4 dag (blindet måler) og livskvalitet (SF-36 spørgeskema) efter 28 dage (blindet måler).

Resultater

Studie I: Patienterne (N=22) i det kvalitative studie deltog i 65 interviews. Sensorisk perception af maden og spise evne var bestemmende for de individuelle sensoriske behov hos ernæringsrisikopatienter (dvs. udseende, aroma, smag, tekstur, temperatur, og variation fødevaresensoriske kvaliteter, der fremmer indtag) indenfor en kontekst af motivation for at spise som: nydelse, komfort, og overlevelse. Disse observationer dannede basis for en model for fødevaresensoriske kvaliteter, der kan fremme kostindtaget.

Studie II: PCA af resultaterne fra spørgeskemaet (N=200) inddelte patienterne efter motivation for at spise: nydelse *vs.* overlevelse, hvilket gav anledning til at fastsætte fødevaresensoriske behov som hhv.: stimulering af appetitten *vs.* facilitering af indtag. Energi- og/eller proteinbalance var positivt associeret med nydelse af maden, præference for forskellige smage, syrligt tilbehør, og sur, krydret og behageligt mættende madvarer og negativt associeret med tvunget kostindtag, lille appetit, tidlig mæthed, maveonde, kvalme, smagsændringer, synkebesvær, kvalmende aromaer, besvær med at danne en bolus, og præference for "lette madvarer", velkendte madvarer og madvarer, der smagte, som det var foretrukket.

Studie III: Interventionsgruppen (N=42) opnåede en højere energibalance (111% vs. 93%, p=0.009) og proteinbalance (96% vs. 82%, p=0.016) end kontrolgruppen (N=39). Energibalancen var ≥ 75% hos 90% vs. 70% (p=0.029) og proteinbalancen var ≥ 75% for 83% vs. 57% (p=0.028) af hhv. interventions- vs. kontrolpatienterne. Interventionsgruppen vs. kontrolgruppen havde forbedret håndgribestyrke efter 3-5 dage (middel 3,0 kg vs. 2,7 kg) og reaktionstid efter 9-11 dage (median -86 ms vs. -49 ms), hvilket var positivt associeret med indtag, men uden differencer mellem grupperne.

Konklusion

Der blev udviklet en model for fødevaresensoriske kvaliteter, der kan fremme kostindtaget hos ernæringsrisikopatienter. Anvendelsen af modellen gennem individualiseret, fødevaresensorisk-kvalitets-baseret ernæringsterapi øgede energi- og proteinindtag hos hospitalsindlagte patienter i ernæringsrisiko sammenlignet med traditionel ernæringspleje. Fysiologiske funktioner blev forbedret inden for få dage med den fødevaresensorisk-baserede ernæringsterapi. Flere studier er nødvendige for at fastslå om anvendelsen af modellen gennem udvikling af brugerdrevet, innovative fødevarer kan demonstrere en øgning i kostindtag i ernæringsrisikopatienter.

1 Introduction

1.1 Hospital undernutrition

Why is it important?

About one-third of hospital patients are at risk of undernutrition,[1] relating to a combination of compromised nutritional status, such as inadequate food intake and loss of lean body mass, and stress metabolism associated with severity of disease.[2] Undernutrition is associated with wide-spread, adverse effects on physiological function, such as poorer muscle and mental function,[3-8] delayed wound healing,[6,9] decreased thermoregulation,[10] impaired immunity and resistance to infection,[11] and compromised organ function,[12] including cardiovascular, renal, respiratory and gastrointestinal function. As a results of these adverse effects, hospital undernutrition has been associated with increased morbidity, prolonged hospital stays, increased healthcare costs, poorer quality of life,[13-15] and higher mortality rates.[16-18] However, these outcome variables have been shown to improve in hospital patients at nutritional risk when adequate nutritional therapy is provided.[17,19-21] In spite of the potential benefits of nutritional therapy, undernutrition continues to be a problem in many hospitals[22-24] and nutritional status often worsens during hospitalisation.[25,26]

What is going wrong?

Many studies have highlighted a widespread problem of insufficient food intake in hospitals.[22,27-29] For example, a study from the UK[27] found that although the hospital menu was nutritional sufficient, providing 10207 kJ and 67 g protein per day on average, daily energy intake was 71-77% of recommendations within all specialties (i.e., mean 5644 – 6057 kJ and 41 – 45 g of protein intake per day). A similar Danish study found that hospital patients ate only enough to cover 60% of their energy requirement (i.e., mean 4500 kJ and 46 g protein per day) despite the fact that food produced by the kitchen provided 40% more than needed to fulfil their energy requirements (i.e., mean 11100 kJ and 112 g of protein per day).[28] A recent Swiss study by Thibault et al.,[22] found that only 31% of hospital patients ate enough to meet their energy and protein requirements from a mean daily intake of 6071 kJ and 62 g of protein, even though the hospital menu supplied 8294 kJ and 83 g protein per day on average. The problem of hospital undernutrition can therefore be largely attributed to inadequate food intake notwithstanding sufficient food provisions.[22,27,28] It also leads to large amounts of plate waste and ineffective use of health care resources.[22,27,28,30] Decreased food intake at meals has in itself been found to be an independent risk factor for hospital mortality even when adjusting for age, severity of disease and length of stay on the day of the survey.[31] This was based on a large cross-sectional international European study,[31] which found that more than half of patients did not complete their meals in hospital.

Why is it going wrong?

An investigation on *Nutrition Programmes in Hospitals* initiated by the Council of Europe in 1999[32] identified five major barriers to adequate nutritional care including lack of: 1) defined responsibility, 2) sufficient education, 3) influence of patients, 4) cooperation among healthcare staff, and 5) involvement from hospital managers. Deficiencies in nutrition care practice were also identified, such as nutritional risk screening generally not being performed, lack of a nutrition steering committee or support team in most hospitals, sparse and inconsistent use of nutritional support, and serving only three meals per day as opposed to six as recommended in some countries.[33] As a result of these findings, the Committee of Ministers of the Council of Europe adopted a *Resolution ResAP(2003)3 on Food and Nutritional Care in Hospitals*[34] which acknowledged that the number of undernourished patients was unacceptable, recognised that nutritional care improves recovery and quality of life, and declared access to a safe and healthy variety of food as a fundamental human right. This resolution also provided a number of recommendations on nutritional care in hospitals.

The Danish experience

About a decade ago, a Danish study,[35] found that only 25% of the hospital patients at nutritional risk received an adequate amount of energy and protein. Nurses were also questioned regarding substandard nutritional care, which was attributed to three major factors: 1) a lack of guidelines for nutritional screening and therapy, 2) insufficient knowledge of nutritional care among the nursing staff, and 3) a lack of appetite and unsuitability of the hospital food.[36]

Improving food intake in hospitals is a complex and multifactorial process.[36] Therefore, a number of initiatives have since been undertaken to improve nutritional care in Denmark and have been shown to improve practice and outcome somewhat.[37-39] Nutritional risk screening (NRS-2002)[40] was implemented as a starting point and is now performed routinely at admission to hospital to identify patients who will likely benefit from nutritional therapy.[41] Furthermore, Danish nutritional care guidelines[42] and resources were published, and educational seminars and quality improvement studies on nutritional risk screening and treatment have been conducted.[37,38] According to a follow-up study,[38] some positive changes were found in attitudes and knowledge about nutritional care among doctor and nurses and practices regarding nutritional risk screening, calculation of nutritional requirements, and availability of guidelines.

The third major factor contributing to inadequate nutritional care, i.e., lack of appetite and unsuitability of the hospital food, was previously recognised as becoming increasingly important once the other factors had been addressed.[35] It had therefore not been a major focus and still warranted further investigation. It is within this context that the current PhD project was initiated.

1.2 Aims and outline of the thesis

The PhD project aimed to establish a framework for developing functional foods, i.e., appetising, energy- and protein-rich foods, for improving food intake in patients at nutritional risk.

To accomplish this aim, the project was comprised of the following three studies.

1. The first study in the project aimed to investigate food sensory quality as experienced and perceived by patients at nutritional risk. This was accomplished by a qualitative study, including observations of patients during meals in hospital and semi-structured interviews focused on food sensory perception and eating ability as related to food quality.

2. A quantitative questionnaire was developed based on the results of this qualitative study for further investigation of patient perceptions of food sensory quality and associations to adequacy of food intake in a larger, heterogeneous group of patients at nutritional risk.

3. The effect of individualised food-sensory-quality-based nutritional care in hospital patients at nutritional risk was investigated by a randomised controlled trial using energy and protein intake, functional measurements (i.e., hand grip strength and reaction time), and quality of life as outcome variables. The food-sensory-quality-based nutritional care used in this study was based on the previous results of the project.

2 Background

The following sections include a review of the existing knowledge on patients' eating-related problems, nutritional care practices to promote food intake in patients, and food sensory quality.

2.1 Eating-related problems in patients at nutritional risk

Patients at nutritional risk are often faced with various eating-related symptoms as a result of their illness and treatments, which result in decreased food intake. For example, low appetite,[43] early satiety,[44] chewing and swallowing problems (e.g., poor dentition, dysphasia),[45,46] dry mouth,[47-49] nausea and vomiting,[50,51] gastrointestinal problems (e.g., dyspepsia, slower gastric emptying, impaired gut function),[44,52] changes in sense of taste and smell[53] are commonly known to negatively affect food intake in patients at nutritional risk. Other factors, such as fatigue,[54] negative mood (e.g., depression or anxiety),[54,55] and physical or mental impairment[56,57] can also affect ability to sufficiently feed ones. Considering that these other factors are also negatively affected by undernutrition,[3-8] further compounds the problem.

Varying prevalence rates of eating-related symptoms have been found in previous studies. Prevalence for low appetite ranges from 10% to 71%,[53,58-62] early satiety from 28% to 51%,[47,53,58,60] dry mouth from 57% to 63%,[47,53,58] nausea or vomiting 11% to 54%,[51,63] taste changes from 28% to 75%[53,58,64] in different patient groups. It should be noted that most of these studies included patients regardless of their nutritional risk status and rates of eating-related symptoms are likely at the higher end in patients at nutritional risk.

2.2 Patients' perceptions of their eating-related problems

Qualitative studies have previously investigated patients' perceptions of their eating-related problems and experiences in different patient groups and varying contexts. Such studies have been conducted in gastrectomy,[65] cancer,[66-68] heart failure,[69] stroke,[56] and gastroenterology[70] patients (see Appendix 1 for a detailed summary of methods and results of these studies). Most studies have had a broad focus and a cross-sectional design, whereas there have been fewer studies investigating specific issues, e.g., chemotherapy-induced taste and smell changes,[67] or longitudinal studies, with multiple follow-up interviews.[67,68] Previous qualitative studies have focused predominantly on describing eating-related and nutritional problems with a more limited focus on concrete solutions to promote food intake in patients at nutritional risk.

Patients described experiencing various eating-related symptoms, including loss of appetite, nausea, vomiting, chewing and swallowing problems, gastrointestinal dysfunction, chemosensory changes, weakness, physical impairments, and pain,[56,65-70] which typically developed gradually and changed a great deal during the course of illness and treatment.[67,68] Some patients also recognised their symptoms as being interrelated, e.g., chemosensory changes causing decreased appetite or nausea.[67] As a result of eating-related symptoms, meals often became unpleasant and food intake

decreased, which was a source of worry for patients that recognised the importance of eating.[56,65-70] In the worst case, eating-related symptoms that caused physical distress, especially nausea and anticipated vomiting, were described as ultimate barriers that completely hindered eating.[68]

Qualitative studies have also described patients' reactions to eating-related problems, which varied widely between patients depending on the meaning that they placed on food,[69] psychosocial factors,[56,68,70] their motivation and engagement,[70] and recognition of the importance of nutrition for recovery and quality of life.[68,70] Patients expressed difficulty in finding appropriate foods and typically ate by trial and error,[67,68] but often gravitated towards previous eating patterns and habits.[65] Different coping mechanisms and techniques were used by patients and their families in an attempt to overcome eating-related problems with varying levels of success to improve food intake.[65-70] Strategies used to promote food intake included: lowering one's expectations to food,[68] self-forced eating,[65] eating smaller portions more frequently,[65,68] eating a set times,[68] watching others eat,[68] nutrient fortification of foods,[66] cooking and serving special foods in different ways,[66] and oral nutritional supplements.[65,66,68]

Patients mentioned that healthcare staff gave limited advice on appropriate food choices in light of eating-related problems, which was sometimes contradictory or caused more problems.[66,67] For example, patients suffering from chemosensory changes were commonly advised to use more salt, resulting in excessive thirst and dry mouth.[67] Patients also generally perceived that there was as a lack of focus on identifying and addressing nutritional problems on part of healthcare staff.[66,67]

2.3 Nutritional care practices to improve food intake

Food intake is considered the first line of defence against undernutrition, whenever possible. Compared to tube feeding or parenteral nutrition, oral food intake is associated with lower risk of complications and side-effects (e.g., infection, aspiration, pathogenic oral flora, overfeeding)[71-74] and more affordable cost.[75,76] According to intervention studies of multimodal nutritional care, about 85% of hospital patients at nutritional risk relied solely on food intake, as opposed to tube feeding or parenteral nutrition, to meet their nutritional requirements.[19,39,77] Evidence-based strategies to improve food intake in patients at nutritional risk include: oral nutritional supplements,[17,78] nutritional counselling, energy- and protein-rich foods,[79,80] fortified-foods,[79,81] between-meal snacks,[81] and optimising the foodservice system[82]

Oral nutritional supplements

Oral nutritional supplements are the most thoroughly studied strategy to improve food intake in patients at nutritional risk and include mostly liquid sip feeds or powders reconstituted to form drinks (e.g., milk- and juice-based beverages) and less often puddings.[83] Systematic reviews and meta-analyses of studies on oral nutritional supplements in patients have reported improvements in clinical outcome, including reduced mortality and fewer complications (e.g., infections, pressure ulcers), especially in acute care and acutely ill geriatric patients.[78,83,84] Most studies found

that oral nutritional supplements consistently increased total energy and protein intake, providing about 1000 to 2500 kJ per day.[78,83]

Studies also suggest that intake of other foods, such as at main meals, is not suppressed by oral nutritional supplements[78,83] even regardless of consumption 30 or 90 minutes before a meal.[85] An increase in daily intake from other foods (mean 5665 kJ *vs.* 4639 kJ) in addition to increased intake from supplements (1968 kJ/day), compared to a control group not receiving supplements, was even reported in a study in gastrointestinal surgery patients.[86] On the other hand, a Cochrane review from 2009[84] on oral nutritional supplements in elderly at nutritional risk suggested that the results on overall food intake should be interpreted cautiously in light of the challenges in accurately assessing food intake and the lack of blinded dietary assessors in most studies.[84] It has also been shown that oral nutritional supplements can suppress intake of other food in the very elderly.[87]

Some studies have highlighted problems with lack of compliance in patients taking oral nutritional supplements.[88-90] For example, poor compliance was found in a study in hip fracture patients[89] on clinical outcome from an oral nutritional supplement (i.e., 1374 kJ from one 235ml can/day) for 28 days following surgery, both in hospital and post-discharge. The study[89] found that compliance was highly variable between patients (i.e., median 20.6, range 0-28 cans/study period) and that 37% of patients consumed the supplement for less than 20 days. A study in elderly patients found that only 43% of the patients consumed more than 80% of the prescribed amount of oral nutritional supplement (i.e., two 250ml cans/day for six weeks).

A study[91] investigating views and attitudes towards oral nutritional supplements in elderly patients and healthcare staff described positive and negative characteristics relating to compliance. Patients that favoured supplements felt that cooling the drinks improved palatability, expressed preferences for specific flavours, and suggested that a food supplement in bar form could be a good idea. On the other hand, patients were against supplements because they made them feel sick, tasted like cement, were too filling, preferred water, and grew to dislike them. Some healthcare staff saw supplements as a good alternative to a meal and as a strategy to improve nutritional and health status, especially in underweight patient, whereas others criticised supplements for: a lack of choice, unappetising appearance, nauseating smell, unpleasant consistency, and for being too much to consume and too sweet.[91]

Reviews of studies on oral nutritional supplements suggest the need to further investigate the optimal consistency and composition of supplements to promote intake.[78] However, most studies have focused on acceptance and palatability of supplements predominantly based on patients' taste preferences for different flavours or brands, or milk-based versus juice-based drinks.[92-99] These studies have typically found a higher preference for fresh, milk-based supplements in patients compared to UHT milk- or juice-based supplements.[92,96,98-100] However, studies were difficult to compare due to varying methodology and supplements being tested.

Additional challenges with compliance to oral nutritional supplements have been observed in cancer patients suffering from taste changes and altered saliva production, especially in relation to chemo- or radiotherapy.[90,92] A review of the literature by Ravasco[90] suggested that cancer patients might benefit from a greater selection of flavours of oral nutritional supplements in relation to changing food preferences over time coinciding with changes in taste. In contrast, a study in gastrointestinal cancer patients found that their taste preferences for oral nutritional supplements were not changed after 6 weeks of chemotherapy.[96]

Nutritional counselling

Nutritional counselling for patients at nutritional risk is typically done by a dietitian or other healthcare staff specialised in nutrition.[101] The advice given focuses on encouraging patients to eat energy- and protein-rich foods and educating about food choice, preparation, and fortification; overcoming eating difficulties; and oral nutritional supplements, if deemed relevant.[102] However, most studies on nutritional counselling neglect to provide information on the nutritional counsellor, the form of counselling, the advice given, and the patients' comprehension of the advice given.[83]

A recent study by Rüfenacht et al.[103] on nutritional counselling versus oral nutritional supplements in undernourished hospital patients (i.e., NRS-2002 ≥ 3 and weight loss ≥ 5% in the last two months) found significant increases in energy and protein intake during hospitalisation in both groups compared to baseline. The patients receiving nutritional counselling were assessed and followed by a dietitian and given fortified foods (e.g., maltodextrin, oil, protein powder), energy- and protein-rich snacks, beverages and oral nutritional supplements. This intervention resulted in more adequate intake in which the patients in the nutritional counselling group met 107% of energy and 94% of protein requirements compared to 90% of energy and 80% of protein requirements in the patients receiving oral nutritional supplements. The study[103] also found an improvement in quality of life at 2 months from baseline in both groups, but with no significant difference between groups.

A Cochrane review from 2008[101] on the effect of dietary advice for disease-related undernutrition in adult patients identified 36 suitable studies, including 12 studies comparing dietary advice plus oral nutritional supplements versus supplements, if required, with no advice. Almost twice as many studies were excluded due to substandard methods or randomized controlled trial design. Energy intake was typically improved in the patients that received dietary advice, although this was not found when comparing energy intake in patients receiving dietary advice versus supplements.[101] Dietary advice versus no dietary advice in a 4-6 month intervention study resulted in a mean 267 kJ/day increase in energy intake, whereas dietary advice plus supplements, if needed, resulted in a mean increase in energy intake of 1373 kJ/day and 1943 kJ/day improvement for 4-6 month and 7-12 month intervention studies, respectively. However, the evidence was found insufficient to draw conclusions regarding contributions from dietary advice versus oral nutritional supplements and effect on clinical outcome and cost.[101]

Energy- and protein-rich foods and between-meal snacks

Early satiety can hinder patients at nutritional risk from eating adequately.[44] However, macronutrients have been shown to affect satiety to different degrees with protein having the highest and fat having the lowest satiating effect per unit of energy.[43] Maximising energy density whilst decreasing the appetising effect of foods through consuming food with a higher fat content is therefore a common strategy used to improve the adequacy of food intake in patients at nutritional risk.[104] Energy-density and portion size have been found to work independently or combined to promote energy intake in healthy subjects, whereas reducing energy density and increasing volume leads to decreased energy intake.[105] Studies in patients have found that serving energy dense and often smaller more frequent portions, e.g., including snacks, can improve energy intake in patients.[79-81,106-109]

Although many energy- and protein-rich foods are available, some foods can be further enhanced through fortification, i.e., adding ingredients, such as oil, butter, cream, cheese, skimmed-milked powder, or commercial powder or liquid supplements.[102] In addition to fortifying foods, serving frequent small-portion meals, including regular between-meal snacks, is another common strategy to promote food intake in patients at nutritional risk. Oral nutritional supplements are often used as between-meal snack and, as mentioned previously, have been found to improve energy and protein intake in patients, without suppressing intake of other foods.[78,83] Other snack foods studied have included dairy products (e.g., yoghurt, cheese, mousse, smoothies, ice cream), baked goods (e.g., cakes, cookies, cereal bars, muffins), savoury snacks (crackers, crisps, sandwiches, soup, ready-made meals) and fruit.[81,109-111] A study on snacks in cancer patients found that the top five preferred foods and top five preferred beverages, in descending order, included: 1) crackers with cheese or peanut butter, 2) doughnuts, 3) fruit cups, 4) oatmeal cookies and 5) applesauce to eat and 1) water, 2) coffee, 3) soft drinks, 4) orange juice and 5) ginger ale to drink.[107]

Food volume as opposed to energy density was more of a limiting factor on food intake in elderly patient in hospital according to a study by Olin et al.[79] Patients in this study received the regular menu (7000 kJ/day) for six weeks followed by an energy-rich version of the menu (10500 kJ/day) for another six weeks. Although no information was given on the specific energy density, it was reported that lunch and supper meals were fortified with natural energy-rich ingredients in the new menu. As a result, patients' energy intake increased by 40% from 105 kJ/kg/day to 147 kJ/kg/day, although the patients' functional status was unchanged. A second study by Olin et al.[80] in elderly nursing home residents found that a similar fortification of the menu increased energy intake from 98 kJ/kg/day to 134 kJ/kg/day and maintained activities of daily living (ADL) function in the intervention group, whereas energy intake was unchanged and ADL function declined in a control group receiving the regular menu. Another study[108] in elderly hospital patients on fortification of the menu with cream, butter and oil found a 37% increase in total energy intake compared to prior intake from the standard menu.

A study[81] in hospital patients investigated the effect of offering afternoon and evening snacks and fortifying the menu, providing an extra 4044 kJ and 22 g protein per day in the intervention compared to the control group that received the regular menu. As a result, energy intake was significantly improved by 1398 kJ/day in the intervention compared to the control group, with greatest effects in patient groups with the lowest intake, although protein intake was not improved at 55 g/day.[81] Another study[106] on the effect of small, fortified meals (i.e., 20% reduced portion size; 837 kJ more energy/day) and snacks compared to the regular menu found similar results in hospital patients. Energy intake was significantly higher by 1197 kJ/day in the intervention compared to the control group, but protein intake was not improved at 49 g/day in this study.[106] A crossover study[109] on a personalised snack-based intervention for 4 weeks in elderly hip fracture patients in hospital found that snacks covered 26% of daily energy requirements at an average of 1727 kJ/ day, but effect on total intake was not reported.

Although results of studies on energy- and protein-rich foods, and snacks seem promising, the evidence base is too limited for drawing conclusions, especially due to a lack of randomised controlled trials on the subject.[83] Also, studies often included all hospital patients, making it difficult to interpret the results for patients at nutritional risk.

Optimising the foodservice system

The most commonly investigated initiative to improve hospital foodservice in the literature has involved a change from plated to point of service meal provision (i.e., decentralisation).[112] Point of meal service provision, also commonly known as a buffet or bulk trolley meal service systems, typically allows for more flexibility of choice and personalised service.[113] A recent review[112] of the literature on point of meal service systems, including 18 studies, found reductions in plate waste and improvements in food intake, patient satisfaction, and cost effectiveness as a result of decentralisation and personalisation of the meal service system. Nine of the studies in the review[112] measured food intake, which improved in all but one of the studies. However, results were difficult to compare between studies[112] because the methods for reporting intake varied widely (e.g., one meal, all meals, or total intake) and all hospital patients were included in the studies regardless of nutritional risk status.

The one study[114] from the review on point of service meal provision[112] that did not find a change in food intake did however find an improvement in patient satisfaction when switching from a plated to a bulk trolley system. This included improved ratings for the overall standard of the catering improved from 76% to 93% and improved ratings for portion size, presentation, appeal, serving temperature, taste, and satisfaction.[114] Similarly, another study found that change from a bulk trolley to a plated system improved food temperatures measured at point of serving and was associated with better patient opinion of the texture overall and of the temperature of the main course meat/fish dish.[115]

In Denmark, there has been a trend towards a higher use of bulk trolley and satellite kitchens (i.e., decentralised) as opposed to centralised plated meal service systems.[116] This trend was reflected in a Danish study[117] on the effect of reorganising a hospital catering system for the evening meal on food intake in patients. The reorganisation being studied involved changing from a centralised plated system with no patient menu choice to a new menu-cart system, offering a selection of small, appetising, energy-rich dishes. The study[117] found that energy and protein intake from the evening meal increased significantly in the quartile of patients with the lowest intake as a result of the changes in the hospital catering system (i.e., mean 128 kJ *vs.* 1021 kJ and 0.7 g *vs.* 8.1 g protein). On the other hand, energy or protein intake remained unchanged in patient eating an average of 2000 kJ and 18-25 g protein at supper.[117] Another Danish study[118] compared the effect of a new gourmet-inspired, *ad libitum* à la carte menu versus a fixed conventional menu in hospitalised cardiology patients. This study found that energy intake increased (i.e., mean 7900 kJ *vs.* 6600 kJ per day) with the new menu. However, protein intake remained unchanged at 17-18% energy, whereas carbohydrate intake decreased from 51% to 42% of energy, and fat intake increased from 32% to 41% of energy. Also, the increase in energy intake was disproportionately higher for patients with a body mass index (BMI) $\geq$ 25.[118]

The study mentioned in the introduction by Thibault et al.[22] was conducted as a comparative study aimed at improving foodservice quality and thereby, ensuring the adequacy of food intake in hospital patients. However, the study found that food intake was unchanged from 10 years ago and remained inadequate (i.e., only 31% of patients met their energy and protein requirements). This lack of improvement was found in spite of efforts to set focus on the problem of hospital undernutrition (e.g., declaration of alimentary rights) and initiatives to improve the quality of the foodservice (e.g., applying nutritional recommendations, patient-self menu selection, changes in meal times, and improved cooking). However, it should be noted that a centralised, plated meal service system was used and as discussed previously, the food quality could perhaps have been improved by point of service meal provision.[112] The study also found that meal quality, as evaluated by patients on a 10-point visual analogue scale (VAS), was positively associated with nutritional intake. Furthermore, a questionnaire with four predetermined categories showed that patients that did not eat all of their food gave the following reasons: absence of menu selection (32%), inadequate taste (25%), inadequate cooking (10%), and/or inadequate mealtime (5%).

In contrast to the food intake studies outlined above, there are also a number of studies that have assessed the success of foodservice systems based on patient satisfaction.[61,119-121] Although food intake was not assessed in many of these studies, a positive association between food intake and patient foodservice satisfaction was assumed. However, there appears to lack evidence for this assumption and there are even studies that suggest the contrary. For example, one of the few prospective studies on food intake at meals in elderly patients by Paquet et al.[122] found through multivariate analysis that food intake was not associated with any measure of patient satisfaction, but was instead associated with patient assessed 'food sensory quality'. The study found that

'food sensory quality' was positively correlated with energy and protein intake even when adjusting for emotions (i.e., positive emotions, anger, anxiety, and mild depressed feelings), patient assessed 'food service quality', and patient satisfaction with the service, food, and overall. 'Food sensory quality' was characterised by tastefulness, appropriateness of temperature and texture, and palatability.[122] In contrast, 'food service quality' (i.e., defined in the study as staff attitude, service timeliness, duration, feeding assistance, sitting position) was surprisingly found to be negatively associated with energy intake.

2.4 Food sensory quality

Definitions

Food sensory quality has been defined as the sensory experience of the colour and appearance, odour, textural properties, tactile properties, and sound of food.[123] In the current project, 'food sensory quality' was investigated in terms of the appearance, aroma, taste, texture, temperature, and variety of food. These attributes are described in more detail in the following sections, including reference to studies in patients and impact on food intake as per available evidence.

Palatability is often used synonymously with 'food sensory quality', but refers more specifically to flavours that are pleasing to the palate and is closely related to liking.[124]

Flavour is often wrongly confused with taste and is a more complex construct involving the perception of a combination of sensory attributes during eating, involving the sense of smell and taste and the somatosensory system (e.g., involving touch, temperature, pain).[125]

Appearance

The appearance of foods, including the colour, physical form and shape, and presentation, is a significant contributor to food sensory quality.[126] Appearance has been found to lead to expectations and associations with the quality of other food sensory properties, including textural properties, flavour, and aroma even before food was tasted.[126] Pictures of meals have therefore previously been used in healthy subjects to assess preferences for varying sensory qualities, but involving much less respondent burden than having to taste the 32-meal combinations tested.[127]

One of the few studies to investigate the effect of the appearance of meals in patients at nutritional risk included a Japanese case study of an undernourished cancer patient receiving chemotherapy and suffering from loss of appetite.[128] Food intake in this patient was improved from approximately 2500 kJ/day to over 4000 kJ/day while reducing meal portions by half in an attempt to improve the appearance. Although this study does not contribute much in terms of scientific evidence since it is only a case-study, the concept of stimulating appetite by reducing 'appearance specific satiety' is an interesting hypothesis.[128] As described previously, studies have found that small frequent fortified meals and/or snacks can increase energy intake in hospital patients, but were discussed more in terms of energy-density as opposed to appearance of

meals.[79-81,106-109] A survey of patients' perceptions of hospital food by Stanga et al.[61] found that almost half of hospital patients agreed that the presentation of food was important.

Aroma

Food odours can be perceived when sniffed (i.e., orthonasally), but can also be perceived in the mouth (i.e., retronasally). As such, aromas are often confused with taste and can influence taste perception.[125,129] Aroma plays an important role in the perception of food flavours and attractive odours can improve palatability.[124] Impaired sense of smell is therefore often associated with changes in dietary habits and decreased enjoyment of eating.[130] On the other hand, foul food odours can alert us to spoiled foods that should be avoided because of risk of illness, such as food borne illness/poising.[131] A study by Yeomans et al.[132] in healthy subjects demonstrated independence between hedonic (i.e., liking) and sensory quality of odours and suggested that acquired liking for flavours might be hunger dependent. Subjects in this study were randomised to consume one of three preloads differing in energy content (i.e., high or low energy soup or water control) prior to rating the sensory and hedonic characteristics of odours from pairing sweet taste (sucrose), bitter taste (quinine), and water. Subjects that received the high-energy preload, inducing lower hunger and higher satiety, had lower liking for a sweet odour compared to subjects that received a low-energy or control pre-load. Liking for a bitter odour and sensory quality ratings of the odours were not significantly different regardless of preload.

A number of disease states and treatments[133] (e.g. head trauma,[134] infection,[135,136] anorexia,[137] neurodegenerative diseases,[138] and cancer chemotherapy[53,122]), undernutrition,[139] and aging[140] have been associated with olfactory dysfunction. A study in patients receiving chemotherapy[53] found that 49% of patients reported changes in sense of smell of which 39% and 32% of patients reported having intermittent or constant smell changes, respectively, lasting for about 1 to 14 days and most often relating to perfume or cooking odours. Another study[122] in chemotherapy patients found that 23% reported smell changes during chemotherapy, but no associations between smell detection thresholds and energy and protein intake were found. Studies in other patient groups, such as HIV-infected patients, found that 47% reported smell complaints and 14% complained of food smelling different.[136] Smell and/or taste disorders in a mixed group of patients were found to be associated with nutritionally important dietary alterations, which depended however upon the nature and severity of the chemosensory changes.[141] For example, distorted or phantom smell and/or taste abnormalities were associated with weight loss, whereas weight gain was associated with simple sensory loss in this study.[141] Food odours have also been related to aversions and inducing nausea as demonstrated by a study, which found that cancer patients with food aversions rated odours, such as chocolate, pork, roast beef and chicken (i.e., food commonly disliked[142]), as less pleasant than a healthy control group.[143] Overall, most evidence suggests that smell abnormalities can negatively affect food intake[144] and a hospital survey found that 40% of patients agreed that the aroma of foods was important.[61]

Taste

The chemosensory receptors (i.e., taste buds) in the mouth and upper throat are capable of detecting the five basic tastes: sweet, sour, bitter, salt, and umami. Chewing, in addition to the sight and smell of foods, stimulates salivary secretions, which act as a food solvent and allow for detection from the taste buds.[145] Aroma can also influence the perception of taste as described previously.[125] The process of tasting is functional as it helps to differentiate between foods that are desirable (e.g., nutritious) or undesirable (e.g., toxic).[125] Taste also plays an important role in the palatability of foods and a good balance of the different tastes and a presence of umami has been shown to optimise palatability of meals in healthy subjects.[124]

As with olfactory dysfunction, a number of diseases, conditions, and treatments have been associated with changes in the sense of taste (e.g., undernutrition,[139] infection,[135,136] liver disease,[139] cancer chemotherapy,[53,122,146] critical illness,[135] and aging[140,147]). Smell and taste changes are often confused since aromas are also perceived in the mouth. Change in oral status related to saliva production (e.g., dry mouth) can affect taste perception because of the important role of saliva as a food solvent and for the function of the taste buds.[145] A study in patients receiving chemotherapy[53] found that 67% of patients reported changes in sense of taste of which 59% and 35% reported having intermittent or constant taste changes, respectively, lasting for about 1 to 14 days with changes in salt, sweet and other tastes being the most common. High use of the category 'other' rather than salt, sweet, sour or bitter to describe the taste affected was interpreted as reflecting the difficulties patients had in distinguishing between basic tastes.[53] Similarly, another study in HIV-infected patients[136] found that 67% reported smell complaints, which related to food tasting different than usual (30%), overall sense of taste (28%), taste of salt (35%), taste of sweet (25%), taste of sour (25%) and taste of bitter (24%). Also, many HIV patients complained that their medications tasted bad and interfered with their sense of taste.[136] Associations between taste and smell changes and food intake were mentioned previously in the section on aroma. Typically, taste changes have been found to negatively affect food intake.[144]

Preferences for the basic tastes have been found to be altered in different patient groups with varying results. For example, a study in Parkinson's disease patients found similar salt preferences compared to a sex- and age-matched control group, whereas for sweet, the patients preferred higher concentrations compared to a highest liking for a moderately sweet taste in the control group. In contrast, a study[148] of hedonic and intensity ratings for sweet, salt, sour and bitter tastes in gastrointestinal cancer patients found a preference for all concentrations of sour tastes and the higher concentrations of salt tastes in patients compared to healthy subjects matched for age, sex, weight and smoking habits. Intensity ratings for some concentrations of sweet, salt and bitter were higher in patients compared to controls, whereas perceived intensity for sour was similar between groups.[148] A comparable study in upper-gastrointestinal or lung cancer patients found that patients receiving chemotherapy had less distinct preferences for different taste concentration compared to patients not receiving chemotherapy.[149] More undernourished patients preferred lower sweet intensities, although sweet foods comprised a

large part of their diet.[149] In another study in cancer chemotherapy patients, sweet and salty foods were reported to be particularly problematic.[142]

Umami is the least commonly known of the basic tastes and reflects the taste of L-glutamate salts in savoury foods, e.g., cheese, bouillon, meat, poultry, seafood, seaweed, and ripe tomatoes.[150] Addition of monosodium glutamate (MSG) to foods has been associated with improved food intake in malnourished elderly and patients and shown to have positive effects on palatability, salivary flow and gut functions.[151] However, umami has been less commonly investigated in patients compared to the other basic tastes. A study in head and neck cancer patients found an impairment in the threshold for umami, which increased significantly during radiotherapy, whereas thresholds for all other tastes increased slightly, but were not significantly different from before radiotherapy.[152] Furthermore, a positive correlation between umami threshold and subjective taste loss was found, but no such correlations were found for the other four basic tastes.[152]

The effect of an intervention aimed at improving the eating experience, and thereby food intake, in patients with chemosensory dysfunction has rarely been investigated. One such study[153] in elderly cancer patients found that an eight-month intervention of flavour enhancers and chemosensory education improved nutritional status (Mini Nutritional Assessment scores) and physical function (quality of life questionnaire) compared to a control group that only received nutritional education. However, food intake was neither improved in the intervention group nor different between groups. The flavour enhancers used in this study included 13 bottles of aromatic essence (e.g., bacon, beef, roasted garlic, mushroom, raspberry, etc.) and the chemosensory education included advice on: use of the flavour enhancers (e.g., not with nausea or during chemotherapy), avoiding certain foods when having a sore or dry mouth (e.g., citrus fruits, hard foods, spicy or salt foods), chewing foods thoroughly to encourage salivation and taste sensation, and increasing variety by foods of different textures and temperatures.[153]

Texture

Food texture can be defined by the rheological/flow and structural (e.g., geometric and surface) properties of foods perceived by mechanical, tactile and, in some cases, visual and auditory sensory receptors.[154] Texture is commonly thought of in terms of oral tactile (i.e., touch) sensation of the, e.g., size, shape, hardness, viscosity and phase change (e.g., melting) of food in the mouth.[154] Oral tactile texture of food can also be described in terms of 'mouth feel', including, e.g., astringency, puckering, tingling, tickling, cooling, numbing, and mouth coating effects of food in the mouth.[154] Food texture is often perceived visually to assess freshness (e.g., wilted spinach or shrivelled grapes not being perceived as fresh).[154] It is also perceived auditorially when mechanically manipulating foods (e.g., chewing), which creates sounds associated with specific textures, e.g., popping sound of wet crispy foods and snapping sound of dry crispy food.[154] Food texture can be an important indicator of food quality more so for some foods (e.g., crisps, steak, celery) than others (e.g., wine, soda).[154] It can also help to identify foods

as demonstrated by a study,[155] which found that only about 40% of different pureed/blended foods could be identified correctly when tested blindly by healthy elderly subjects. This study[155] also found that some pureed food items were easier to identify than others, e.g., 81% identified blended apples correctly, whereas only 4% could identify blended cabbage. Another study[124] in healthy subjects found that the palatability of meals can be improved by using a combination of hard and soft textures (e.g., crispy, crunchy, juicy, smooth, creamy, tender).

Studies in healthy individuals have found that liquid, especially low viscosity liquids,[156] as opposed to solid foods promote food intake.[157,158] For example, a study[159] in healthy elderly found that intake of a liquid versus solid food was subsequently associated with higher hunger and lower satiety in spite of comparable energy content and macronutrient composition of the foods. This effect could perhaps be attributed to satiety signals from chewing and oral stimulation by solid foods[157] as well as faster gastric emptying and transit time of liquids compared to solid foods.[160,161] However, results of studies on the effect of solid versus liquid foods on hunger and satiety have varied depending on the subjects, oral state (e.g., mouth dryness), and the food being tested.[162]

Food texture has been studied in patients most commonly in relation, e.g., dysphasia, poor dentition or other conditions requiring a texture modified solid foods and/or liquids. Texture modified diets are commonly categorised as, e.g., liquid, thin purée, thick purée, soft, and minced,[163,164] but evidence on the clinical efficacy of these diets is scarce.[165] Some studies have found that texture modified diets are nutritionally inadequate and are associated with insufficient food intake in patients.[29,166] For example, a study in elderly hospital patients[166] found that patients on a texture modified diet had significantly lower mean energy and protein intake compare to patients on a normal diet (i.e., 3877 kJ *vs.* 6115 kJ and 40 g *vs.* 60 g protein per day, respectively). However, another study in institutionalised elderly patients with dysphasia demonstrated that a new modified texture menu with improved food quality, variety and choice resulted in higher energy and protein intake in patients on the new menu compared to patients on the standard modified texture menu (i.e., mean 6557 kJ *vs.* 5640 kJ and 56 g *vs.* 53 g protein, respectively).[165] Furthermore, a study[167] in nursing home patients found that texture modified diets were often misprescribed since 91% of the patients with feeding and/or swallowing disorders were on the wrong diet (e.g., many were on liquid or purred diets, although a soft diet was safe). A study[168] investigating visual plate waste in a heterogeneous group of hospital patients found that the odds of plate waste increased 344% for patients on a modified consistency diet, decreased 61% for patients on a diabetic diet, and increased 14% for every day admitted to hospital, whereas gender and diagnosis were not associated to plate waste.

Temperature

Nerve endings in the mouth are used to sense food temperatures and can assess changes in temperature as little as 1ºC, occurring more rapidly for increases than decreases in temperature.[125] Food temperature can greatly affect the physical and chemical properties of foods, thereby

influencing the quality of other food sensory properties.[123] Foods and beverages typically have expected serving temperature, which if inappropriate can decrease acceptance or liking. As mentioned previously, hospital foodservice systems aim to maintain the proper serving temperature of foods, which can be optimised by point of meal service provision with associated improved food intake in patients.[112] Stanga et al.[61] found that about 70% of hospital patients agreed that the temperature of foods was important.

Food variety and sensory specific satiety

'Sensory specific satiety' refers to the reduction in palatability during consumption of a monotonous food, while palatability is maintained when offering a variety of different foods.[169] This implies that satiety can be specific to a particular food.[169] Furthermore, the variety of the sensory properties of foods and meals has been shown to promote energy intake in healthy subjects.[170-173] This was demonstrated in a study by Hollis et al.,[171] which found that healthy subjects ate more when offered four varieties of sandwiches served in succession compared to a monotonous serving of the same sandwich four times in a row. When comparing younger and elderly subjects (i.e., mean 27 and 70 years old) in this study,[171] it was found that older subjects ate significantly more than the younger subjects during the monotonous serving of sandwiches. In contrast to these results, it was previously found that elderly subjects had diminished sensory specific satiety, which was assumed would be associated with a monotonous diet and a lower caloric intake[174] A second study[175] in healthy subjects investigating the termination of a meal consumed ad libitum (i.e., two courses separated by an hour's break) found that that the most common reason for stopping eating in the first course was "I got tired of eating that food" compared to "I felt full" in the second course. Also, this study found that subjects that terminated their meal based on fatigue or decreased palatability, indicative of sensory specific satiety, ate less at the meal than subjects that terminated their meal based on feeling full (i.e., 1076 kJ *vs.* 1775 kJ). Lastly, a third study in healthy subjects[176] investigated the effect of the volume versus energy content on the decrease in palatability following consumption (i.e., sensory specific satiety) of a 300ml drink providing 2067 kJ. The study[176] found that doubling the volume consumed without changing the energy content (i.e., 600ml, 2067 kJ) resulted in increased sensory specific satiety, whereas doubling the energy content of a beverage with the same volume (i.e., 300ml, 4134 kJ) had no additional affect on sensory specific satiety.

Evidence is limited on the effect of food variety and sensory specific satiety in patients at nutritional risk. In a recent study in anorexia nervosas patients,[177] 4-day food records were completed following in-patient treatment and the reported diet was scored for the energy density and variety. The study found that a lower diet energy density score was significantly associated with poorer clinical outcome (i.e., Morgan-Russell criteria for anorexia nervosas outcome), but no association was found for the dietary variety score. However, the authors of this study recognised that patients with anorexia nervosas are noted for over-report food intake, which could have influenced the accuracy of the diet energy density and variety scores. In another study on sensory specific satiety,[130] consumption of repeated fixed portions of the same food item (i.e.,

to induce sensory satiation) in patients with partial or complete loss of smell compared to healthy controls, matched for age, sex and education level, found no evidence that olfactory function affected satiation for sensorially monotonous foods. This study was initiated based on other findings that sensory specific satiety did not require food to enter the gastrointestinal system and could be induced simply by smelling or chewing foods for the approximate time period it would take to eat.[178]

3.1 Overview of the study methods

Table 1 – Overview of the study participants, design, and methods used in *Study I, II* and *III*.

Study	Participants	Design	Data collection and analysis
I.	Hospital patients at nutritional risk from gastrointestinal surgery, oncology, infectious medicine, cardiology, rheumatology, and hepatology wards. (N=22)	Prospective longitudinal qualitative study.	Meal observations (food choice, hunger/fullness/appetite scores); 3-day dietary records and photos of meals 2 weeks post discharge; semi-structure qualitative interviews on food sensory perception and eating ability as related to food quality (interviews done after meals in hospital and 2 weeks post-discharge; N=65). Interviews were transcribed, coded and analysed thematically.
II.	Hospital patients at nutritional risk from infectious medicine, cardiology, gastrointestinal surgery, rheumatology, oncology, and haematology wards. (N=200)	Cross-sectional questionnaire study.	Questionnaire developed based on the results of *Study I* and comprised of questions about patients' eating-related symptoms (15 three-point scale questions), and food sensory needs and motivation to eat (46 Likert scale questions). Demographic and questionnaire results were assessed in relation to energy and protein intake. Principal component analysis (PCA) was used to assess associations between variables.
III.	Hospital patients at nutritional risk from cardiology, infectious medicine, oncology, haematology, and rheumatology wards. (N=81)	Randomised concealed allocation, assessor-blinded, controlled trial.	Patients were randomised to individualised food-sensory-quality-based nutritional care inspired by *Study I* and *II* (intervention) or usual care (control). Food and activity records were completed daily. Handgrip strength, reaction time, weight and bioelectrical impedance were assessed every 3-4 days in hospital. Quality of life (SF-36) was assessed after 28-days. Intention-to-treat or complete case analyses were done.

3.2 Project and study design

Qualitative study (Study I)

Considering the potentially large complexity of patients' perceptions of food sensory quality and the limited existing evidence on the subject in patients at nutritional risk, a qualitative study approach was chosen as a starting point in *Study I*. The qualitative study design had the advantage of being exploratory and flexible in nature to produce in-depth, descriptive data from which new hypotheses and a framework for food product development in patients at nutritional risk could be developed. Also, the prospective, longitudinal design and variety of methods (e.g., meal observations, ratings of hunger, satiety and appetite, 3-day food records post-discharge, photos of meals, and semi-structured interviews) were used to give a well-rounded insight into patients' experiences and perceptions of food sensory quality and factors related to their food choice.

Questionnaire study (Study II)

Study I had its drawbacks since the factors identified could not be quantified and as such, *Study II* was initiated. A quantitative patient food choice questionnaire was developed based on the factors identified in *Study I*. This questionnaire was used to assess the prevalence of eating-related symptoms and factors related to food sensory needs and motivation to eat in a large heterogeneous group of hospitalised patients at nutritional risk. Also, associations with energy and protein intake and between variables could be assessed using univariate and principal component analysis (PCA), respectively. This approach of using mixed methods to investigate a topic (e.g., direct meal observations and quantitative interviews in *Study I* and qualitative interviews in *Study II*) is also known in social sciences as 'triangulation',[179] which helps to give a deeper understanding of the topic at hand.

Food sensory studies

The project had originally intended to develop a number of functional foods, i.e., appetising, energy- and protein-rich foods, with satisfactory sensory qualities to promote food intake in patients at nutritional risk. The effect of these foods on intake and outcome was then to be tested in a randomised controlled trial (*Study III*). Food sensory studies were conducted on developed products and meals as based on the results from *Study I* and *II*. These studies involved assessment of change in appetite and satiety during intake of food and rating on the food sensory quality using the Sussex Ingestion Pattern Monitor (SIPM) system.[180] However, in light of the complexity and diversity of the food sensory needs of patients at nutritional risk (*Study I* and *II*), a satisfactory selection of foods was not successfully developed within the time and resources available of the current project. Therefore, this part of the project has not been a focus of the current thesis and the effect of individualised food-sensory-quality-based nutritional care based on the results of *Study I* and *II* was investigated instead in *Study III*.

Randomised controlled trial (Study III)

To conclude the project, it was considered essential to test the efficacy of applying the developed framework from *Study I* in a clinical setting. This was accomplished by a randomised controlled trial of the effect of individualised, food-sensory-quality-based nutritional care on food intake and outcome in patients at nutritional risk. The design included: minimisation randomisation[181,182] (i.e., patients stratified according to department, NRS-2002 intake score, and HGS as a percent of standard for age and sex[183]), concealed allocation, assessor-blinding, and intention-to-treat analysis. Patients were individually randomised to one of two parallel groups with varying nutritional care regimens: current practice and general nutritional advice (control group) or individualised, food-sensory-quality-based nutritional care consisting of appetising, energy- and protein-rich foods determined by the patient's eating-related symptoms, food sensory needs, and motivation to eat, which was assessed using the patient food choice questionnaire from *Study II* (intervention group). Outcome variables included average daily energy and protein intake, change in physiological functions (i.e., handgrip strength (HGS), reaction time (RT) and bioelectrical impedance analysis (BIA)) during hospitalisation and quality of life after a 28-day.

Study timelines

All studies were prospective, conducted over a period of about 4 weeks (*Study I* and *III*) or cross sectional (Study II). The times lines for *Study I* and *III* are shown in Figure 1.

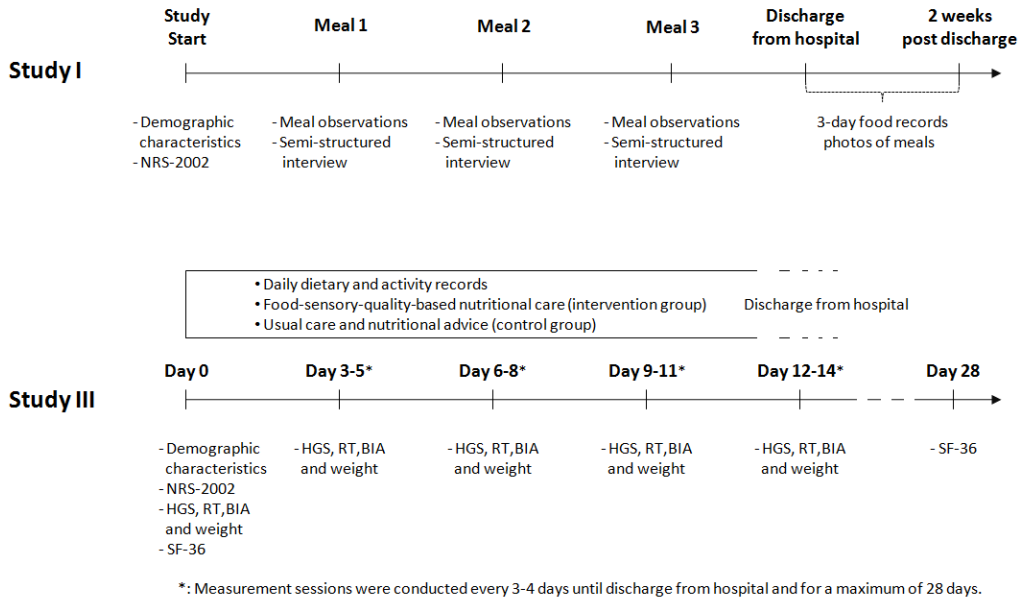

Figure 1 – Timelines for the qualitative study (*Study I*) and randomised controlled trial (*Study III*).

3.3 Participants

Study participants were recruited from selected, non-intensive care departments (i.e., gastrointestinal surgery, oncology, infectious medicine, cardiology, rheumatology, hepatology, and haematology departments) at Copenhagen University Hospital (Rigshospitalet). The hepatology department was only involved in *Study I* and later declined to participate in subsequent studies. The haematology department was therefore invited to join the project in *Study II* and *III* to increase recruitment possibilities. The gastrointestinal surgery department was not included in *Study III* because most patients with a projected LOS ≥ 5 days were on enteral or parenteral nutrition. As a result, only internal medical patients were included in *Study III*, which also promoted greater homogeneity, similarly as was done in a study by Starke et al.,[19] which found positive effects on outcome in mixed internal medicine patients.

All adult patients (≥ 18 years old) found to be at nutritional risk (NRS-2002[40] ≥ 3) at admission to hospital or at weekly re-screening were assessed for participation in the different studies. NRS-2002 risk status is defined by a presence of undernutrition and/or risk for undernutrition (e.g., severity of disease as related to nutritional requirements). It was chosen as an inclusion criterion because it indicates potential benefit from nutrition therapy, which has been validated by a literature analysis of 128 randomised controlled trials[40] and a separate randomised controlled trial.[39] Patients were excluded if they were unable to communicate coherently (e.g. mental illness, cognitive impairment, or language barriers), were acutely ill, had participated in the study previously, or did not provide informed consent. Plans to start enteral or parenteral nutrition or inability to eat normally were also reasons for exclusion. In *Study III*, patients were also excluded based on compromised physical function, impeding their ability to complete study measurements, such as handgrip strength. Patients were excluded from *Study I* if they were one-day admissions and from *Study III* if their expected length of stay (LOS) in hospital was shorter than five days in order to allow for adequate follow-up.

3.4 Study setting

Rigshospitalet is an acute-care, tertiary hospital with 1200 beds divided into units comprised of 15–20 beds. Three main meals are prepared in the central hospital kitchen by cook-chill, cook-freeze and based on a 5-week menu rotation. Main meals are served buffet style on the unit and are expected to cover two-thirds of requirements. The three main diet types include the 'hospital diet' with higher energy and protein density than the 'normal healthy diet' and 'vegetarian diet'. Breakfast is a standard assortment (e.g., yogurts, cereals, porridges, bread, cheeses, and fruit), lunch comprises of a selection of open-faced sandwiches, an entree and soup, and supper consists of a choice of 3 different menus followed by dessert. The remaining third of requirements are fulfilled by snacks, drinks, and frozen, microwaveable meals available from satellite kitchens on the units and nutritional supplements. Patients at nutritional risk can be prescribed the 'Super diet', which is an à la carte menu with optimised energy and protein density, quality and selection of meals. The 'Super diet' includes a selection of breakfast items, sandwiches, various cold and warm lunch and supper dishes, side dishes, desserts and snacks.

Menu items can be ordered directly from the kitchen by telephone. Modified consistency and therapeutic diets or ethnic menus are also available.

3.5 Data collection and outcome

Baseline data and follow-up

Baseline characteristics collected in the studies included: gender, age, department, diagnosis, hospital LOS at study start, and nutritional status (e.g., weight, BMI, intake, weight loss and NRS-2002[40] scores). In *Study I* and *II*, immigrant status and educational level was also recorded. In the longitudinal studies (*Study I* and *III*), follow-up data was collected on length of stay and discharge destination (i.e., home, nursing home, or death). A thorough daily follow-up was done in *Study III*, including collection of data on the patient's medical condition, treatments and procedures (e.g., complications, surgery, fasting, home leave from hospital) and presence of oedema/ascites. Also, complications were entered from a list of complications with definitions based on Buzby et al.[184]

Dietary and activity recording

Daily dietary records were completed by the patient and/or nursing staff on forms customised for the hospital foodservice, i.e., using weighed reference portions for the hospital menus and food items. Energy and protein content of foods was based on Danish nutritional data from the Master Cater System (Anova Data, Holte, Denmark). Portion size of food items was assessed visually in quartiles[79] and for beverages and liquid food items in millilitres. Records were checked using 24-hour recall, which was used instead if dietary records could not be completed by the patient and/or nursing staff.

Daily activity records were completed by the patient and checked by the investigator during daily follow-up. The activity level for each hour of the day to the precision of 15 minute intervals was entered in terms of 'lying sleeping', 'lying awake', 'sitting', 'walking', and 'training' with corresponding activity factors of 0.9, 1.2, 1.3, 2.5, and 7, respectively.[185,186] The daily activity factor was then calculated by the sum of hours spent on each activity multiplied by its activity factor and then divided by 24 hours.

Estimation of requirements

Energy requirements were calculated using the factorial, which has been used in liver cirrhosis patients[187] and evaluated in a heterogeneous group of patients.[186] This method involves calculation of the patient's basal metabolic rate using the Harris Benedict equation, multiplied by an activity factor and a stress factor. The activity factor is described in the previous section and the stress factor of 1.2, 1.3 or 1.4 was used for patients with fever of 38ºC, 39ºC or 40ºC, respectively.[188] Actual, measured body weight was used in the calculation except for obese patients (BMI>30kg/m^2) in which adjusted body weight, based on the metric Hamwi method,

was used.[189] Protein requirements were set at 18% of energy requirement in accordance with the elevated needs of patients as compared to healthy individuals and current practice at the hospital.

Energy and protein balance was calculated in terms of percent of estimated requirements met by the daily intake.

Meal observations and semi-quantitative interviews (Study I)

During meal observations in hospital, patients were instructed to eat wherever and whatever they preferred and comments were written by the investigator on patient food choice, eating behaviour, duration of meals, eating environment, and foodservice. Photos were taken of the food and drink eaten before and after meals. Patients also rated their hunger and fullness on 150-mm VAS directly before and after meals and VAS ratings of the appetising effect of the meal once finished eating as based on Yeomans et al.[190] Amount of meal eaten was assessed visually[79] from the before and after photos of meals as intake quartiles[79] as the percent of a meal portion of 2000 KJ and used to group patients based on their intake. A semi-structured interview was conducted directly following the meal which focused on the patient's experiences and preferences regarding food sensory quality including the appearance, taste, aroma, texture, temperature and variety of the meal that was eaten. Changes in the patient's sensory perception and/or eating ability or emerging themes (i.e., newly identified topics found to be relevant to the study's aim) were also discussed in relation to their perception of food sensory quality. Within the first couple of weeks following discharge from the hospital to home, a 3-day food record and photos of meals were taken by the patients using a disposable camera and sent to the investigator by mail. Semi-structured interviews based on these records were repeated by phone approximately two weeks post-discharge.

Patient food choice questionnaire (Study II)

The patient food choice questionnaire consisted of 15 eating-related symptoms, which were rated for severity on a three-point scale, and 46 statements on food sensory experiences and preferences and motivation to eat, which were rated for agreement on a five-point Likert scale. The questionnaire was developed in Danish as shown in Appendix 2 and translated into English as shown in Appendix 3. The content and wording of the questionnaire was developed based on the results of *Study I* in collaboration with the co-authors and colleagues that provided interdisciplinary perspectives and revised based on pilot-testing in hospitalised patients (N=13). Questionnaires were interviewer administered in hospital and patients were advised to reply based on their current condition.

Measurements session: physiological function and weight (Study III)

Measurements session were conducted at the bedside by a trained, blinded outcome assessor at baseline and every 3 to 4 days thereafter until discharge from hospital in the following order: weight, handgrip strength (HGS), reaction time (RT), and bioelectrical impedance analysis (BIA).

HGS was measured using GripTrack Hand Dynamometer (JTECH Medical, Salt Lake City, United States). Patients were tested on their dominant side, while seated, with their shoulder adducted, their elbow flexed 90°, and their forearm in a neutral position.[191] Maximal isometric hand grip strength was measured three times with the handle in the second position, using standard encouragement and about 15 seconds rest between trials. An average of the three trials was calculated.

The Go/No-Go (5 stimuli, 2 targets) subtest of the Test for Attentional Performance version 2.1 (TAP 2.1; PsyTest, Herzoganrath, Germany) was used to measure RT. Patients were seated in front of a laptop monitor and instructed to react as accurately and quickly as possible to visual stimuli by pressing a button with the index finger of their dominant hand. The Go/No-Go test involved 60 stimuli presented over 165 seconds during which patients were to react only to two out of five possible figures (i.e., two targets and five different stimuli). Results of the test included their median response time in milliseconds (ms), and total errors, and omissions during the test.

BIA was performed using EFG (Akern/RJL Systems, Florence, Italy), which is a whole body (hand-to-foot), single frequency analyser producing an alternating current of 330 μA at 50 kHz. Patients were measured in the supine position with their arms spread 30º from their torso and legs 45º apart. Electrodes were placed in a tetra polar arrangement on the dorsal surface of the right hand and wrist, and the anterior surface of the right food. The BIA measurements included reactance (Xc), resistance (R), capacitance (C), and phase angle (PA).

Quality of life (Study III)

Quality of life was measured at baseline and on the 28th study day in hospital or post-discharge using the Short Form 36 Health Survey version 2.0 (SF-36v2™), comprised of 36 questions on functional health and well being.[192] The SF-36 questionnaire was completed independently by the patient if possible or interviewer administered and was returned by posted or completed over the telephone post-discharge. The QualityMetric Health Outcomes™ Scoring Software 2.0 was used to compute the eight-scale profile (i.e., physical functioning, role physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health scales) and psychometrically-based physical and mental health component summary scores.

3.6 Statistical analysis

Descriptive statistics were presented as mean ± standard deviation (SD) or median (interquartile range (IQR)) for parametric or nonparametric continuous variables, respectively, and as number (percent) (N (%)) for categorical variables. The Student's t/Mann-Whitney U test, paired-t/Wilcoxon signed-rank test, ANOVA/Kruskal-Wallis H and Pearson/Spearman rank correlation test were used for parametric/nonparametric independent comparisons, paired comparisons, multinomial comparisons, and correlation analyses, respectively. Ordinal comparisons were done using the Jonckheere-Terpstra test. Categorical data was assessed using

Pearson's chi-square or Fisher's exact test. Analyses were conducted using SPSS (version 17.0, SPSS Inc, Chicago, USA). Statistical significance was set at $p<0.05$ and non-significant results were denoted as NS. Study specific data analysis methods are described below.

Qualitative study (Study I)

Interview audio recordings (14.4 hours; median 12.9 minutes/interview) were transcribed verbatim and analysed using a thematic coding framework based on the interview guide (i.e., changes in food sensory perception and eating ability, food sensory quality properties, and emerging themes, e.g. motivation to eat). All transcripts were coded by the first author using qualitative data analysis software, ATLAS.ti 5.0, from which it was possible to extract reports of text excerpts for each code. Sub-codes (e.g., specific tastes and textures/consistencies of foods) and grouping positive or negative statements further facilitated analysis of the data.[193] This process was done in conjunction with continual referral to the full interview transcripts, meal observations, and/or patient characteristics to provide context to the specific text excerpts. An analysis summary document was drafted by the first author and reviewed, discussed, and commented on by all authors and focus group with colleagues, providing interdisciplinary perspectives on the themes. Illustrative quotations were extracted from the interview transcriptions and translated from Danish to English.

Questionnaire study (Study II)

Principal Component Analysis (PCA) was used to examine association between variables and identified patterns of correlation structure in the patient demographic, nutritional status, and patient food choice questionnaire results. PCA transforms a set of possibly associated observed variables into a smaller set of unassociated principle components denoted by PC1, PC2, PC3, etc., which account for descending amount of variability in the data (i.e., PC1 accounts for the greatest variability). PCA score plots and loading plots provided graphical representation of patients and variables, respectively, in relation to the principal components. Patients were segmented according to their PCA scores (i.e., positive PC (+) *vs.* negative PC (-)) and compared using Mann-Whitney U test. Variables on opposite ends along a PC-axis of loading plots suggests negative correlation and vice versa. PCA was conducted using PLS toolbox (version 5.0.3 (Eigenvector Research Inc., Wenatchee, USA) for MATLAB (version 7.10.0 (R2010a), The MathWorks, Natick, USA).

Randomised controlled trial (Study III)

Analyses were to be done by intention-to-treat, i.e., including all patients retained in the group to which they were allocated regardless of protocol violations. However, there were some missing follow-up observations that had to be considered. The analyses done for energy and protein balance, HGS, weight, LOS, discharge destination, and complications were considered less cause for concern as per no or a low rate of missing observations. On the other hand, the analyses done for RT, BIA, and SF-36 were more reflective of complete case analysis due to a higher

number of missing observations. These analyses were therefore interpreted with more caution and baseline characteristics of patients analysed *vs.* patients with missing observations were compared and if suspected of bias, potential interactions were tested using generalised linear models (GLM). Also, measurement sessions with incomplete physiological function results (e.g., RT, BIA) were analysed by the next observation carried backwards or the last observation being carried forward as specified in the results section. Per-protocol analysis, excluding treatment failures (i.e., patients that received enteral or parenteral), was done for comparison. Analysis of change in physiological function and weight was done for changes from baseline to 3-5 days, 6-8 days, 9-11 days, 12-14 days and final (i.e., last measurement session).

3.7 Ethical considerations

All study protocols were approved by the local Biomedical Ethics Committee for The Capital Region of Denmark. In accordance with ethical principles, patients were provided with verbal and written information on the study. They were also informed that participation was completely voluntary and that they may revoke their consent and withdraw from the study at any time. Patients that were interested in a study were required to provide informed consent in order to participate. Information concerning patients that participated in a study was protected under the Act on Processing of Personal Data and the Act on Patients' Rights. Out of ethical responsibility, nutritional advice was given following the semi-structured interview to those that had questions or displayed an inappropriate understanding of nutrition (*Study I*).

4 Results

The following sections provide a summary of the main findings from the project. The results from the qualitative and questionnaire studies (*Study I* and *II*) were highly complementary and are therefore presented together in sections '4.1 Eating-related symptoms', '4.2 Food sensory needs', '4.3 Motivation to eat', and '4.4 Model of food sensory quality to promote intake'. Lastly, the results from the randomised controlled trial (*Study III*) are given in section 4.4.

4.1 Eating-related symptoms (*Study I & II*)

The severity of eating-related symptoms affecting patients (e.g., low appetite, early satiety, dry mouth, taste changes and nausea) were found to be related to lower energy and protein balance as shown in Table 2. Patients often struggled through trial and error to determine what and how much they should eat and drink and would have appreciated more guidance regarding appropriate menu choices for their specific situation. There was however large inter- and intra-individual variation in patients' reactions to changed food sensory perception and eating ability. If food sensory quality was unacceptable, some patients stated that they were more likely to push a meal aside when ill as compared to when healthy. In contrast, other patients were surprised by the conditions under which they were still capable to eat. Patients that experienced a long course of illness with varying eating-related symptoms sometimes had difficult remembering their food preferences. Patients were also typically not conscious of their altered demands to food sensory quality to promote intake in relation to their symptoms.

Table 2 – Patient food choice questionnaire: top five most common eating-related symptoms.

Symptom	'Not at all'	'Somewhat'	'Very much'	Energy balance [a]	Protein balance [a]
Low appetite	30 (15%)	63 (32%)	107 (54%)	Lower, $p < 0.001$	Lower, $p < 0.001$
Early satiety	42 (21%)	56 (28%)	102 (51%)	Lower, $p < 0.05$	Lower, $p < 0.05$
Dry mouth	67 (34%)	62 (31%)	71 (36%)	NS	NS
Taste changes [b]	83 (42%)	65 (33%)	50 (25%)	Lower, $p < 0.05$	NS
Nausea	104 (52%)	73 (37%)	23 (12%)	Lower, $p < 0.05$	Lower, $p < 0.01$

Results expressed as N (%). (N=200), [a] Jonckheere-Terpstra test for ordinal comparisons of energy/protein balance. [b] Two patients with missing answers on taste change due to interviewer oversight. (N=198)

4.2 Food sensory needs (*Study I & II*)

Appearance: Patients stated that meal appearance was important for their appetite. For example, patients appreciated meals comprised of small portions that were carefully arranged on the plate. Some patients preferred garnished meals, whereas others preferred plain and simple meals. Familiar foods were often preferred, but in some cases, led to great disappointment if the food did not meet the patient's expectations due to their changed sensory perception and/or eating ability.

Aroma: Some patients with low appetite found that the aroma of particular foods promoted their desire to eat (e.g., fresh bread, toast, sausages, soup, pancakes, rice). On the other hand, certain and/or general food smells were deemed revolting by other patients particularly those with nausea.

Taste: Most patients preferred natural flavours, which were rewarding to be able to taste in patients with chemosensory changes. Some patients preferred mild or neutral flavours because other flavours seldom lived up to expectations. Patients often had difficulty discussing foods in relation to specific tastes. However, some patients described cravings for specific tastes, e.g., sour tastes were desired for being refreshing and thirst-quenching. Although the term umami was unfamiliar, some patients desired foods with stronger umami flavours (e.g., bouillon, soups, tastier cheeses, sausage). Taste changes and aversions were often confusing for patients especially when previous favourite foods were suddenly avoided completely.

Texture: When meals were an unpleasant or painful process, patients wanted to get over and done with eating as quickly as possible. Therefore, foods that were easy to eat were often chosen and soft and fluid foods were favoured. Patients suffering from dry mouth appreciated meals being served with an excess of sauce, dressing or anything to give moisture. Patients were generally critical of food textures that made meal situations more strenuous. In contrast to favouring easy-to-eat foods, some patients were observed choosing food that were more difficult to eat in an attempt to get back to their usual food routines. Most patients preferred eating a variety of textures and consistencies, if they could manage.

Temperature: Many patients ate and drank slowly and as a result, temperature of meals and beverages often became compromised resulting in diminished quality and desire to continue eating or drinking.

Variety: Variety was considered important, but patients' needs for variety varied. For example, patients that had difficulty eating often required a varied menu selection in order to find what they could manage to eat and drink and then stuck to that. In contrast, other patients appreciated a variety of choices so that they did not get bored of eating the same things from day to day. Lastly, some patients got quickly bored of eating a particular dish, but could perhaps be tempted to eat a different dish.

Patient food choice questionnaire: The questionnaire statements on food sensory experiences and preferences that were found to be related to energy and/or protein balance are given in Table 3. The top five statements that patients fully or partially agreed upon were: Q6: appetising appearance (94%), Q10: taste of raw ingredients (93%), Q5: small portions (87%), Q20: preferred taste (86%), and Q30: refreshing/thirst quenching (82%). The top five statements that most evenly split patients (i.e., smallest difference between agree *vs.* disagree) were: Q44: eating as per recommendations, Q17: variable taste changes, Q19: spicy foods decreasing desire to eat, Q21: easy to eat, and Q40: eating only when hungry.

Table 3 - Patient food choice questionnaire: food sensory preferences and experiences.

Section	Questionnaire statement [a]	Agree [b]	Energy balance [c]	Protein balance [c]
Appearance	Q1: prefer familiar foods	72%	Lower, $p < 0.05$	Lower, $p < 0.05$
Aroma	Q8: nauseating aroma problems	56%	Lower, $p < 0.01$	Lower, $p < 0.01$
Taste	Q11: prefer sour foods	53%	NS	Higher, $p < 0.05$
	Q12: prefer sour side dishes	69%	Higher, $p < 0.05$	NS
	Q13: prefer savoury foods	74%	Higher, $p < 0.01$	Higher, $p < 0.05$
	Q16: prefer different tastes	77%	Higher, $p < 0.01$	Higher, $p < 0.05$
	Q20: preferred taste is important	86%	Lower, $p < 0.05$	Lower, $p < 0.05$
Texture	Q24: difficulty forming a bolus	58%	Lower, $p < 0.05$	Lower, $p < 0.01$
	Q26: prefer 'light foods'	61%	Lower, $p < 0.01$	Lower, $p < 0.05$

Results expressed as N (%). (N=200)

[a] Only statements significantly related to energy and/or protein balance are included.

[b] Percent of patients (N=200) that fully or partially agreed with each statement is shown.

[c] Jonckheere-Terpstra test for ordinal comparisons of energy/protein balance.

4.3 Motivation to eat: pleasure, comfort and survival (*Study I & II*)

Motivation to eat emerged as a theme in *Study I* as it provided an important context for understanding patients food sensory needs and was related to energy and protein balance in *Study II* (Table 4). Three key motivational factors were categorised as: pleasure, comfort and survival. These motivational factors often worked in combination and to varying degrees in a single meal. Patients that found eating pleasurable typically had milder eating-related symptoms and preferred foods that awakened their appetite through varied food sensory properties. Patients motivated by comfort ate foods in order to improve their physiological and/or psychological comfort (e.g., foods perceived to be pleasantly satiating, refreshing, and familiar). Patients motivated by survival typically had more severe eating-related symptoms and chose simple foods that were easy to eat.

Table 4 – Quotes and questionnaire results on motivation to eat (*Study I* and *II*).

Section	Illustrative quotes (*Study I*)	Questionnaire statements (*Study II*)	Agree [a]	Energy balance [b]	Protein balance [b]
PLEASURE	*When I eat something I like, then my appetite also comes.*	Q41: I enjoy my food.	65%	Higher, $p < 0.001$	Higher, $p < 0.001$
		Q42: It is important for me to enjoy my food to eat.	74%	NS	NS
COMFORT	*It's to rinse it down… I like apple. It has a fresh taste.*	Q30: I prefer food that is refreshing and thirst quenching.	82%	NS	NS
	The comfort and enjoyment of eating now is based on its satiating effect.	Q31: I prefer food that is pleasantly satiating.	75%	NS	Higher, $p < 0.05$
SURVIVAL	*I eat because I want to survive this. I know if I don't get anything to eat then it's my own grave that I'm digging.*	Q45: I often force myself to eat.	60%	NS	Lower, $p < 0.05$
		Q46: I eat to overcome my illness.	78%	NS	NS

[a] Percent of patients (N=200) that fully or partially agreed with each statement is shown.

[b] Jonckheere-Terpstra test for ordinal comparisons of energy/protein balance.

Pleasure: The patient's enjoyment of food before becoming ill combined with their current ability to enjoy meals determined the extent that pleasure was a motivating factor to eat. Some patients could still enjoy their meals to some degree and appreciated sensorially varied foods to heighten their appetite. Patients who previously took great pleasure in eating found unpleasant meal situations to be very distressing.

Comfort: Foods that alleviated eating-related symptoms and promoted physiological comfort were sought after, whereas foods that exacerbated symptoms were strictly avoided. For example, patients were motivated to eat foods that were stomach settling, pleasantly satiating, thirst quenching, refreshing or that masked unpleasant tastes in the mouth. Patients also described being motivated to get back to their usual eating routines and found psychological comfort in eating familiar foods.

Survival: Most patients regarded adequate food intake as necessary for overcoming their illness and some were motivated by professional nutritional recommendations. Patients sometimes forced themselves to eat, but did not always succeed to eat adequately. Patients that ate based on survival typically experienced more severe eating-related symptoms. As a result, they were often not as interested to experience their food and aimed to complete their meals as efficiently as possible.

4.4 Model of food sensory quality to promote intake in patients (*Study I & II*)

Patients displayed individualised food sensory needs due to changes in their sensory perception and eating ability, which corresponded to changes in their motivation to eat by: pleasure, comfort and survival as shown in Figure 2 (*Study I*). The first category in the model, pleasure, was a motivating factor for patients, typically with mild symptoms, in which food could be enjoyed somewhat. Appropriate foods in this context awakened appetite through appearance, aromatic smells, tastefulness, and greater variety and complexity of the sensory properties. The second category, comfort, motivated patients to eat foods that gave physiological or psychological comfort (e.g., refreshing, pleasantly satiating, or familiar). The third category, survival, included patients motivated to eat in order to recover from their illness. Some of these patients had given up on enjoying food due to severe eating-related symptoms. Foods to promote intake in this context were plain and simple and had a texture and consistency that facilitated eating.

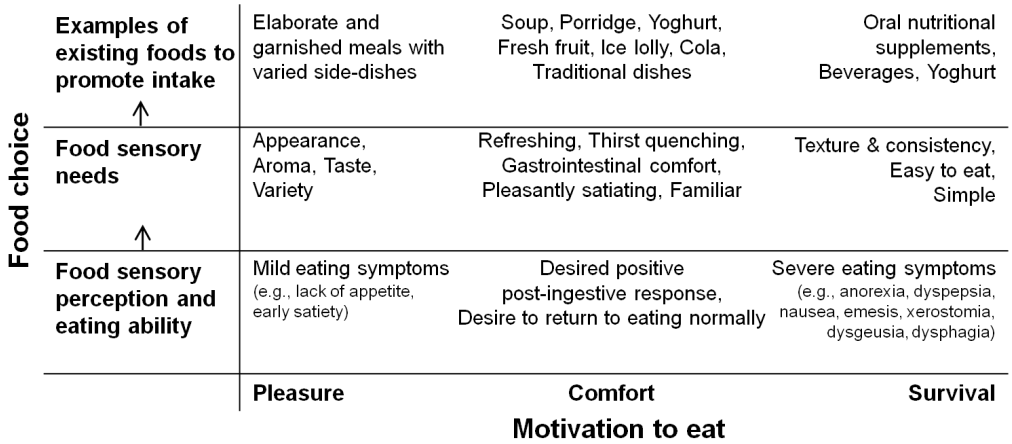

Figure 2 - Model of food sensory quality to promote intake in patients at nutritional risk (*Study I*).

The process of choosing foods (y-axis) within the context of motivation to eat (x-axis) is shown. Food sensory perception and eating ability profiles correspond to specific food sensory needs (i.e., appearance, aroma, taste, texture, temperature and variety of the food), which coincides with examples of existing foods with sensory qualities to promote intake.

The contrast between 'forced eating' *vs.* 'enjoy eating' is shown in Table 5 (*Study II*).

Table 5 – Patient characteristics by PC1 (*Study II*).

Group [a]	Nutrition	Symptoms	Food sensory experiences	Food sensory preferences	Motivation
PC1 (+) *Forced eating* (n=102)	NRS intake score	Low appetite Early satiety Nausea Vomiting Mouth pain Stomach pain Problems chewing Problems swallowing Diarrhea Taste changes	Q8: nauseating aroma Q24: difficulty form bolus Q25: film left in mouth Q33: temperature problems Q32: consistency important Q35: sensory specific satiety Q37: don't know what to eat Q38: difficulty tolerating food Q39: redundant food choices	Q1: familiar foods Q5: small portions Q18: mild flavours Q19: not spicy Q21: easy to eat Q22: soft/fluid Q23: moisture giving sauces	Q45: forced eating Q46: eat to overcome illness
PC1 (–) *Enjoy eating* (n=98)	Energy balance Protein balance	NS	Q7: aroma increases appetite	Q13: savoury Q27: crispy/crunchy Q16: varied tastes Q34: varied dishes Q28: varied textures	Q41: enjoy food

[a] Patient segment group names are based on the authors' interpretation of the results. (N=200)

Mann-Whitney U test of positive *vs.* negative side of PC1-axis PC1 (+) *vs.* PC1 (-).

Variables were included in the table based on $p<0.01$. NS = Not significant.

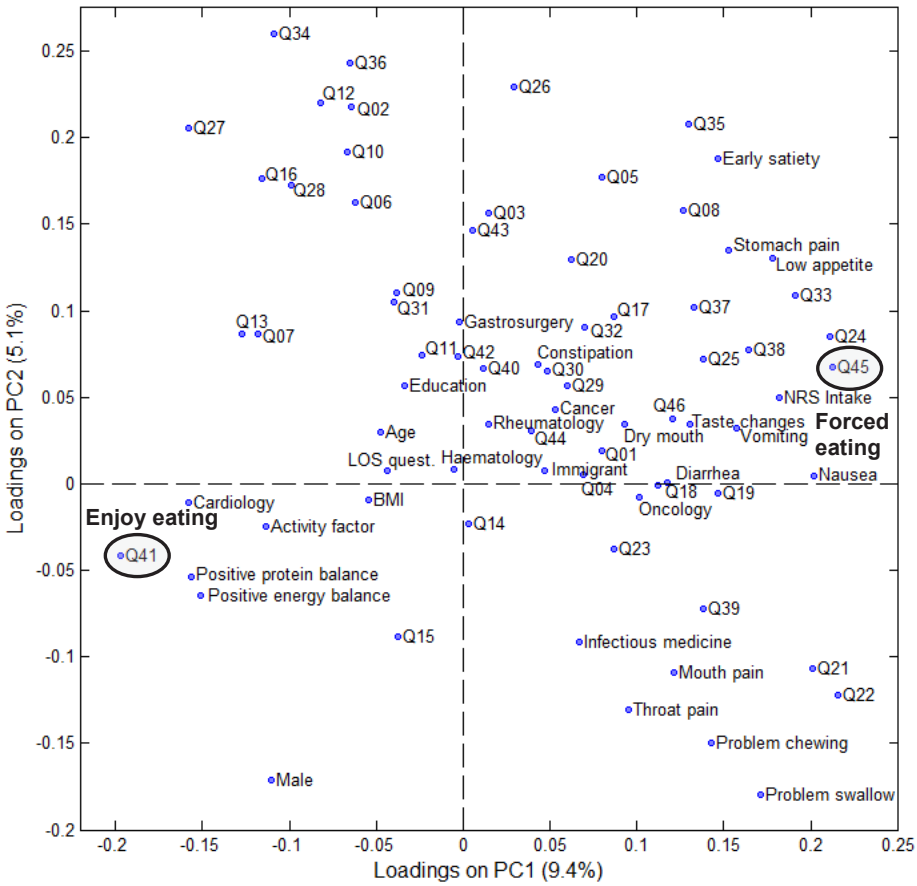

Figure 3 – Loading plot of PC1 *vs.* PC2 (*Study II*).

Refer to Table 5 for a description of variables with the highest absolute PC1 loading values and Appendix 2 & 3 for a full description of the patient food choice questionnaire variables.

PC1 was characterised by 'Q45: forced eating' on the positive side and 'Q41: enjoy food' on the negative side of the loading plot (Figure 3). PC1 (+) was associated with many eating-related symptoms and problematic food sensory experiences (Q8, Q24, Q25, Q33, Q35, Q37, and Q38), a preference for milder flavours (Q18 and Q19), foods that were easy to eat (Q21), familiar foods (Q1), and eating soft or fluid foods (Q22), a view of food as important for recovery (Q46), forced eating (Q45) and the NRS intake score (i.e., history of low intake). PC1(-) was related to enjoying food (Q41), a preference for varied food sensory properties (Q16, Q34, and Q28), a higher activity factor, and positive energy and protein balance, and inversely related to eating-related symptoms.

4.5 Randomised controlled trial (*Study III*)

The randomised controlled trial aimed to investigate the effect of food-sensory-quality-based nutritional care (intervention group) compared to usual care and nutritional advice (control group) on energy and protein intake, physiological function (i.e., HGS and RT), and quality of life in hospital patients at nutritional risk. The intervention group in this study had higher energy and protein intake than the control group and HGS and RT improved after 3-5 days in both study groups, but did not differ between groups, as explained in more detail in the following sections.

Energy and protein balance

Mean daily energy and protein intake during the study period in hospital was significantly higher in the intervention group compared to the control group (energy: 8051 ± 2222 kJ *vs.* 6763 ± 2061 kJ, $p = 0.010$; protein: 73.8 ± 21.2 g *vs.* 63.1 ± 21.3 g, $p = 0.031$). The percent of estimated energy and protein requirements fulfilled by intake (i.e., energy and protein balance) was also higher in the intervention group than the control group as shown in Table 6. Energy balance was ≥ 75% in more intervention patients than control patients (i.e., 90% *vs.* 70%, p = 0.029) and protein balance was also greater ≥ 75% in more intervention patients than control patients (i.e., 83% *vs.* 57%, p = 0.028). Significantly more intervention patients (89%) than control patients (66%) with intake < 75% of requirements the week prior to the study improved their intake to ≥ 75% energy balance while receiving nutritional care in the study (p = 0.015).

Nutritional care intervention

Nutritional care lasted 8 (4 – 20) and 10 (7 – 14) median (IQR) days in the intervention group and control group, respectively, which was not significantly different. Intervention patients covered significantly more of their energy and protein requirements from normal food (i.e., excluding enteral and parenteral nutrition, protein powder and oral nutritional supplements) compared to control patients (energy: 98 ± 28% *vs.* 81 ± 29% (p = 0.039); protein: 82 ± 24% *vs.* 70 ± 28% (p = 0.040), mean ± SD). Food intake from meals and specific food items in the intervention group compared to the control group is given in Table 6. Coverage of energy and protein requirements by lunch and snacks meals and from the 'Super diet', desserts, 'marzipan, candy, and nuts' and ice cream was significantly greater in the intervention group compared to the control group.

Percent of protein intake from snacks was found to be positively correlated to energy balance (p = 0.013) and percent of energy and protein intake from 'marzipan, candy, and nuts' was found to be positively correlated to energy balance (p = 0.005 and p = 0.004) and protein balance (p = 0.041 and p = 0.033). Furthermore, percent of energy and protein intake from cream (p = 0.015 and p = 0.013) and from ice cream (p = 0.029 and p = 0.019) was positively correlated to energy balance. On the other hand, energy intake from 'juice, and soft drinks' was negatively correlated to protein balance (p = 0.016).

Table 6 – Coverage of energy and protein requirements during the study period (*Study III*).

	Intervention group (N=40)		Control group (N=37)	
	Energy (%) [c]	**Protein (%) [c]**	**Energy (%) [c]**	**Protein (%) [c]**
Total energy/protein balance	111 ± 27**	93 ± 31*	96 ± 31**	82 ± 28*
MEALS				
Breakfast [a]	13 ± 7	10 ± 7	12 ± 7	9 ± 6
Lunch [a]	17 ± 8*	15 ± 7*	12 ± 8*	11 ± 7*
Supper [a]	22 ± 9	23 ± 10	18 ± 10	20 ± 11
Snacks [b, d]	12 (5 – 23)*	6 (2 – 12) *	6 (4 – 11)*	3 (2 – 6) *
Beverages & liquids [a, e]	45 ± 19	41 ± 17	42 ± 24	37 ± 23
FOOD ITEMS [f]				
'Super diet' [b, f]	7 (0 – 24)***	7 (0 – 22)***	0 (0 – 2)***	0 (0 – 2)***
Desserts [b]	12 (6 – 17)¤	4 (1 – 5)*	7 (4 – 13)¤	2 (1 – 3)*
Marzipan, candy, nuts [b]	2 (0 – 8)*	1 (0 – 7)*	0 (0 – 1)*	0 (0 – 1)*
Ice cream [b]	1 (0 – 4)¤	0 (0 – 2)*	0 (0 – 1)¤	0 (0 – 1)*

Values shown as mean ± SD[a] or median (IQR). (N=77)

[b] Student's t-test or Mann-Whitney U (between groups): ¤$p < 0.04$, *$p < 0.02$, **$p < 0.01$ ***$p < 0.001$.

[c] Total energy/protein intake as a percent of total energy/protein requirements during the study period.

[d] Solid food items consumed between main meals.

[e] Beverages and liquid food items consumed during and between meals and enteral and parenteral nutrition.

[f] Only specific food items that were significantly different between study groups are included in the table.

[g] Appetising, energy- and protein-rich meals, desserts and snacks prescribed for patients at nutritional risk.

Physiological function and weight

A median (IQR) of 3 (2 – 5) and 4 (2 – 5) measurement sessions were conducted in the intervention group and control group, respectively (NS between study groups). The intervention *vs.* control group had improved handgrip strength after 3-5 days and reaction time after 9-11 days, which was positively associated with intake, but did not differ between groups. Change in body weight was not significant within or between study groups from baseline to final. Furthermore, change in BIA, including resistance, reactance, phase angle, and capacitance, was not significantly different within or between study groups from baseline to final and at specific periods between measurements (i.e., 3-5 days, 6-8days, 9-11 days, and 12-14 days). Measurement session results for HGS and RT at different time points are outlined in Table 7.

Table 7 – Change in handgrip strength and reaction time during the study period (*Study III*).

Variable	Group	Baseline	3-5 days	6-8 days	9-11days
N	Intervention	42	28	20	13
	Control	39	25	27	16
	Control	76.6 ± 21.1	79.8 ± 23.8	77.7 ± 23.8†	83.3 ± 22.9
HGS, kg [a]	Intervention	24.3 ± 13.1	25.0 ± 15.2¤	28.0 ± 14.0‡	26.8 ± 13.9
	Control	23.9 ± 8.0	25.7 ± 8.0†	25.5 ± 8.3†	25.2 ± 9.4
N	Intervention	35	16	12	10
	Control	32	15	17	11
RT, ms [b]	Intervention	657 (581 – 766)	655 (570 – 741)	603 (531 – 678)	573 (537 – 654)‡
	Control	628 (565 – 748)	560 (536 – 677)°°	526 (505 – 650)°°°	549 (513 – 602)‡
RT, errors [b, c]	Intervention	3.0 (0 – 13.0)	0 (0 – 1.5)	0 (0 – 1.5)	0 (0 – 1.5)†
	Control	2.5 (0 – 11.0)	1.0 (0 – 7.0)	0 (0 – 4.0)	0 (0 – 0)

Values shown as mean ± SD [a] or median (IQR) [b]; Mann-Whitney U; HGS: handgrip strength, RT: reaction time.

[c] Total count of both errors and omissions during the RT test.

Paired t-test from baseline within groups: Weight: *$p < 0.05$, ¤$p < 0.04$, †$p < 0.03$, ‡$p < 0.02$, °°$p < 0.005$, °°°$p < 0.002$.

Improvement in HGS was seen after 3-5 days (3.0 ± 7.3 kg and 2.7 ± 5.5 kg) and after 6-8 days (3.1 ± 5.3 kg and 3.9 ± 8.7 kg) in the intervention group and control group, respectively (NS between groups). Average daily energy and protein intake during the first three days in the study correlated with change in HGS from baseline after 3-5 day (energy: r = 0.37, p = 0.006; protein: r = 0.35, p = 0.012). Furthermore, average daily energy and protein intake from the fourth to the sixth day in the study correlated with change in HGS from baseline after 6-8 days in the study (energy: r = 0.45, p = 0.002; protein: r = 0.39, p = 0.008).

Improvement in RT was significant for both the intervention *vs.* control group at 9-11 days (median (IQR) -86 (-223 - -32) *vs.* -49 (-148 – 12), NS between groups). Energy and protein balance for the seventh to the ninth day in the study was negatively correlated with change in RT from baseline to 9-11 days in the study (energy: r = -0.441, p = 0.045; protein: r = -0.429, p = 0.052). Significant reduction in RT errors at specific time points was only seen in the intervention group at 9-11 days and a trend of reduction in errors was seen at 6-8 days in the intervention group (p = 0.057). About a third of patients (intervention: 33%, control: 31%) were missing a follow-up RT.

Quality of life

When comparing change in SF-36 between study groups, increases in general health and physical component summary scores were significantly higher in the control than in the intervention group. However, based on lower general health scores (39.8 ± 21.5 *vs.* 54.4 ± 16.8 mean ± SD, $p = 0.047$) and higher likelihood to be discharged home (86% *vs.* 44%, $p = 0.017$) in the control *vs.* intervention patients with SF-36 lost to follow-up, the effect of these potential interactions were assessed. General linear models with study group, discharge home, and the interaction term (study group x discharge home) were used to assess for potential interactions. Effect of the study group was no longer significant in the model for general health (NS for all variables) and the model for physical component score (NS for all variables).

5 Discussion

5.1 Food quality for patients at nutritional risk (*Study I & II*)

Motivation to eat: pleasure, comfort, and survival

A main finding from this project was that patients' motivation to eat provided an important context for their food sensory needs regarding the appearance, aroma, taste, texture, temperature, and variety of foods. This was initially observed in the qualitative study (*Study* I) in which three key motivating factors were identified as: pleasure, comfort, and survival.

Patients that ate for pleasure typically had milder eating-related symptoms, such that they could still enjoy eating. These patients appreciated more elaborate meals with varied food sensory properties to awaken their appetite. In stark contrast, patients that ate solely for survival typically had the most severe eating-related symptoms and just wanted to complete their meals as efficiently as possible. These patients appreciated simple foods with texture that facilitated eating. This contrast between eating for pleasure *vs.* eating for survival was outlined in the model of food sensory quality to promote intake in patients at nutritional risk (Figure 2). The PCA results of the questionnaire study (*Study II*) segmented patients into groups of 'enjoy eating' *vs.* 'forced eating' (Table 5 and Figure 3). The characteristics of 'enjoy eating' *vs.* 'forced eating' patients were highly reflective of observations of patients eating for pleasure *vs.* eating for survival in the qualitative study (*Study I*). Another important finding from the questionnaire study (*Study II*) was that patients who forced themselves to eat were associated with about 20% lower energy and protein balance compared to patients who enjoyed eating. This suggests that more focus should be given to patients who force themselves to eat. In the questionnaire study (*Study II*), 60% of patients agreed that they often forced themselves to eat, whereas 65% of patients agreed that they enjoyed their food. The concept of self-forced eating has been described previously in qualitative studies,[65,70] but associations with food intake were not assessed in these studies.

The 'forced eating' patient segment group (*Study II*) was associated with more severe eating-related symptoms compared to the 'enjoy eating' patient segment group. The five most common eating-related symptoms and percent of patients affected were: low appetite (86%), early satiety (79%), dry mouth (67%), taste changes (58%), and nausea (49%). Apart from dry mouth, these symptoms were found to be to be significantly related to lower energy and protein balance. These findings are in line with the results of a study in advanced cancer patients, which found that patients' energy intake was inversely related to their lack of appetite, nausea, and early satiety.[64] Another study in a heterogeneous patient population also found positive associations between appetite and food intake.[61]

The 'forced eating' patients, who were associated with severe eating-related symptoms, were also associated with a number of eating-related problems, e.g., difficulties forming a bolus, challenges with nauseating aromas, problems with the temperature of foods, unpleasant films left in the

mouth, and difficulty tolerating foods. Foods for these patients must be able to promote intake in light of these eating-related problems. This could perhaps be accomplished by, e.g., foods with optimal textures that facilitate ease of eating, appetising yet low odour intensity foods, foods with optimal quality at room temperature, refreshing and mouth-cleansing foods, and foods that give a positive post-ingestive response. Facilitating eating through optimal food textures was reflected in the food preferences of 'forced eating' patients, who preferred foods that are east to eat. Also, promoting intake through foods with positive post-ingestive response aim at improving physiological comfort and thereby, involve an additional dimension of motivation to eat by comfort.

Motivation to eat by comfort was also included in the model of food sensory quality to promote intake in patients at nutritional risk (Figure 2). Comfort related to eating based on a desire for a positive post-ingestive response (e.g., thirst quenching or pleasantly satiating foods) or return to eating normality (e.g., familiar foods). The concept of eating for comfort was previously described in a qualitative study in patients with heart failure,[69] but relationships to food sensory quality or intake were not assessed. Statements on motivation to eat by comfort in the questionnaire study (*Study II*) referred to preferences for foods that were refreshing and thirst quenching (Q30) and pleasantly satiating (Q31), which was agreed upon by 82% and 75% of patients, respectively. A preference for foods that are pleasantly satiating was associated with higher protein balance. Previous studies have found that isoenergetic consumption of protein is more satiating than carbohydrate or fat.[194] However, it is difficult to say if foods perceived as pleasantly satiating can help to promote intake in patients at nutritional risk or if patients that prefer pleasantly satiating foods have higher protein balance due to other factors. According to the PCA analysis of the questionnaire study (*Study II*), statements regarding comfort were not found to be associated with 'forced eating' or 'enjoy eating' patient segment groups. Based on the results of both the qualitative study (*Study I*) and questionnaire study (*Study II*) motivation to eat by comfort appeared to be a more universal motivating factor in patients at nutritional risk, which was independent of motivation to eat by survival or pleasure.

Appearance

The largest majority of patients (94%) agreed that an appetising appearance of their food was important for them to eat and many patients (87%) agreed to prefer being served small portions. This suggests the potential benefit of serving small frequent, visually appealing meals to patients at nutritional risk. Other studies have found that serving small frequent meals through fortification of foods and between meal snacks can improve food intake in patients at nutritional risk.[79-81,106-109]

A preference for familiar foods was found to be negatively associated with energy and protein balance and was also found to be associated with 'forced eating' patients (*Study II)*. This might seem surprising considering that, in practice, patients at nutritional risk commonly choose foods based on their previous preferences, often including familiar foods. Patients in the qualitative

study (*Study I*) found comfort in getting back to their normal eating routines and in the questionnaire study (*Study II*), 72% of patients agreed to preferring familiar foods. These finding are consistent with a qualitative study in gastrectomy patients, which also described patients attempting to get back to their previous eating routines.[65] However, eating familiar foods was observed to be problematic in the qualitative study (*Study I*) when patients insisted upon maintaining their usual eating routines despite eating challenges that hindered their ability to eat adequately. Familiar foods also led to great disappointment when they did not meet up to expectations of the food sensory properties as a result of eating-related symptoms. Previous studies in healthy subjects have found that past experiences with a food item have important implications for the perceived quality.[195] For example, consistently high quality food items that suddenly do not meet previous expectations have a much greater impact on perceived food quality than food items without established expecations.[195] Considering these findings, familiar foods with less defined expectations surrounding the sensory properties might be more successful at promoting intake in patients at nutritional risk. Also, it was suggested in the qualitative study (*Study I*) that food intake could perhaps be promoted in patients by developing familiar foods adjusted to compensate for abnormal food sensory perception and eating ability. In contrast, oral nutritional supplements, which could be considered unfamiliar food items, have been shown to improve food intake in patients at nutritional risk,[78,83,84] although compliance has been problematic in some studies.[88-90]

Aroma

Nauseating food aromas decreased the desire or ability to eat of 56% of patients in the questionnaire study (*Study II*) and were associated with lower energy and protein balance. Nausea, as an eating-related symptom, affected 49% of patients and was also associated with lower energy and protein balance. A qualitative study in advanced cancer patients[68] on strategies to compensate for anorexia found that nausea or anticipated vomiting was commonly named as an ultimate barrier to eating. On the other hand, many patients (79%) in the questionnaire study (*Study II*) agreed that the aroma of some foods promoted their desire to eat, but this question was not found to be associated with energy or protein balance. Catering to the contrasting needs of patients regarding food aroma is a challenge, but considering the association between nauseating aromas and lower food intake, care should be taken to shield affected patients from nauseating food aromas.

Taste

The questionnaire study (*Study II*) found that a preference for sour foods and sour side dishes was associated with higher energy and protein balance, respectively. This might indicate potential benefits of sour foods to promote intake in patients at nutritional risk or else is related to other characteristics of patients that prefer sour foods that relate to higher food intake. Studies in cancer patients[96,99] found greater preference for fresh milk-based nutritional drinks, which were more sour and less sweet in one study.[99] Patients in qualitative study (*Study I*) also expressed an

appreciation for being able to taste fresh, natural flavours as opposed to artificial flavours, especially when struggling with taste changes. This finding was reflected in the questionnaire study (*Study II*), which found that 93% of patients felt that it was important to be able to taste the raw ingredients of food. Another study investigating taste preferences of oral nutritional supplements in a heterogeneous group of malnourished hospital patients[98] found a greater preference for milk-based supplements than for sweet or salty juice based supplements. Another study in gastrointestinal cancer patients found a higher liking of sour beverages compared to other tastes as compared to healthy controls.[148] Sour tastes were also referred to as being refreshing and thirst quenching by some patients in the qualitative study (*Study* I). Sour tasting beverages have previously been associated with refreshing properties in healthy subjects.[196]

A preference for more umami-rich foods (i.e., savoury foods) was associated with higher protein balance in the questionnaire study (*Study II*). This perhaps suggests benefits of savoury foods to improve food intake or could relate to umami-rich foods high in protein (e.g., cheese and sausage) or other characteristics of patients that prefer umami-rich foods. Addition of monosodium glutamate (MSG), a savoury flavour enhancer, to foods has been associated with improved food intake in malnourished elderly and patients and shown to have positive effects on palatability, salivary flow and gut functions.[151]

Preferring different types of tastes was related to higher energy and protein balance, whereas the importance of food tasting as preferred in order to eat was related to lower energy and protein balance. Preferring different types of tastes was also associated with the 'enjoy eating' patient segment group in the questionnaire study (*Study* II). It might therefore be a characteristic of patients with milder eating-related symptoms that can enjoy their foods and thereby, eat more adequately. Furthermore, eating meals with varied sensory properties has been found to promote intake in healthy subjects.[170] As with familiar foods, the importance of eating foods tasting as preferred could relate to lower food intake when well established taste preferences do not meet up to expectations of taste due to changed food sensory perception.[195] The importance of food tasting as preferred was not associated with the 'enjoy eating' or 'forced eating' patient segment groups and might reflect a personal trait independent of eating for pleasure or survival. In contrast to this, a qualitative study[67] in chemotherapy cancer patients found that patients with chemosensory patients sometimes gave up on the taste of foods and chose neutral foods instead. This was also observed in the qualitative study in which patients with taste changes explained that they were less likely to be disappointed by neutral tasting foods (*Study I*). A study in advanced cancer patients[68] described lowering one's expectations to food as a coping mechanism to deal with eating-related problems.

Texture

Difficulty forming a bolus was associated with lower energy and protein balance. It was also strongly associated with the 'forced eating' patient segment group in the questionnaire study (*Study II*). It might therefore be a characteristic of patients with severe eating-related symptoms

that force themselves to eat and thereby, struggle at eating adequately. 'Forced eating' patient were also associated with eating only soft and fluid foods and preferring easy-to-eat foods and moisture giving sauces. Studies in healthy subjects have found that liquid versus solid foods can promote food intake[157-159] and have been associated with higher hunger and lower satiety ratings despite similar energy content and macronutrient composition of the foods being tested.[159] This effect has been attributed to satiety signals from oral stimulation related to chewing solid foods[157] and faster gastric emptying and transit time of liquids versus solid foods.[160,161]

About two-thirds of patients agreed to prefer 'light foods' rather than fatty foods (*Study II*). Some patients in the qualitative study (*Study I*) described preferring 'light foods', e.g., fruits and vegetables, because they found them refreshing and pleasantly satiating in contrast to fatty foods. A preference for 'light foods' is consistent with findings from previous studies in hospital patients, which found that fruit was popular,[197,198] especially when feeling unwell,[199] and certain vegetables were preferred.[197] A study on food preferences in cancer patients[200] found that fruits, vegetables, and cultured dairy products were the only food groups in which liking was not significantly different between patients, patients with aversions, and healthy controls. Liking for other food groups in this study[200] was lower in patients compared to healthy controls. A preference for 'light foods' was also found to be related to lower energy and protein balance in the questionnaire study (*Study II*). This is not surprising considering that studies on food fortification have found that serving energy dense meals, typically with increased fat content, can improve energy intake in patients at nutritional risk.[79,81,106,108]

Temperature

In the qualitative study (*Study I*), many patients were observed eating and drinking slowly, which sometimes compromised the food temperature and quality, resulting in decreased desire to continue eating. However, only 40% of patients agreed that they experienced such problems with food temperature in the questionnaire study (*Study I*), which was not found to be associated with energy or protein balance. Previous studies have found that the hospital foodservice system can impact the serving temperature of foods in which point of service systems have been found to optimise serving temperatures and food quality of foods.[114,115] A buffet foodservice system was used at the hospital of the current project, which might have led to patients experiencing fewer food temperature problems.

Variety

Patients in the qualitative study (*Study I*) expressed different needs for food variety. Some patients needed a varied menu selection in order to find foods that they could tolerate for a period, whereas other patients preferred eating varied foods from day to day and/or meals with varied food sensory properties to increase their desire to eat. These contrasting needs for food variety were consistent with the food sensory experience and preference that characterised the patient segment groups of 'forced eating' versus 'enjoy eating', respectively, in the questionnaire study (*Study II*). 'Forced eating' patients were associated with difficulty tolerating foods and

redundant food choices, whereas 'enjoy eating' patients were associated with preferences for varied tastes, textures, and dishes.

About half of the patients in the questionnaire study (*Study I*) agreed to quickly losing their desire to eat a particular food, but that they were perhaps being able to eat something else. This statement from the questionnaire study (*Study II*) intended to refer to the concept of sensory specific satiety, i.e., the reduction in palatability experienced when eating monotonous foods. In the qualitative study (*Study I*), some patients expressed that they got quickly bored of eating a particular dish and appreciated meals comprised of varied small attractive dishes. It was suggested therefore that meals comprised of multiple components and/or courses could perhaps help to minimise the effect of sensory specific satiety and perhaps promote food intake. In healthy subjects, the variety of food sensory properties has been shown to promote energy intake,[170-173] but evidence of the effect of food variety in patients at nutritional risk is limited. Experience of sensory specific satiety was not found to be related to energy or protein balance in the questionnaire study (*Study II*). However, this could have relate to the hospital diet that the patient was on (e.g., the normal diet, the 'Super diet', or a modified consistency diet).

5.2 Food-sensory-quality based nutritional care (*Study III*)

This project had originally intended to develop a number of functional foods, i.e., appetising, energy- and protein-rich foods, with sensory properties conducive to promote intake in patients at nutritional risk. The effect of these foods on intake and outcome was then to be tested in a randomised controlled trial (*Study III*). Another intervention approach was however chosen based on the complexity and diversity of the food sensory needs of patients at nutritional risk as found in the qualitative and questionnaire studies (*Study I* and *II*). Instead of testing a newly developed food product, the results from the previous parts of the project were applied in an intervention of individualised, food-sensory-quality-based nutritional care. The specific meals, foods, and beverages offered to patients in the intervention group were determined based on the patient's food sensory needs and motivation to eat as assessed by the patient food choice questionnaire (*Study II*) and ongoing follow-up during the study period in hospital.

Previous randomised controlled trials on the effect of predominantly food-based nutritional care in hospital have typically provided limited information on the specific foods used in the intervention group compared to the control group and associations with adequacy of food intake.[19,39] This is unfortunate considering that such information is helpful when interpreting the results of the study and would be useful regarding further application in clinical practice and future research. In light of the focus of this project on foods to promote intake in patients at nutritional risk, it was considered essential to be able to report the differences in food being eaten in the intervention group compared to the control group and associations with energy and protein balance. Therefore, detailed results on the energy and protein intake from different meals and specific food items commonly used in the nutritional care intervention were compared between study groups and associations with energy and protein balance were assessed.

The randomised controlled trial (*Study III*) demonstrated that patients in the intervention group had significantly higher energy and protein intake and balance than patients in the control group. This was accomplished by a higher intake of normal foods (i.e., excluding enteral and parenteral nutrition, oral nutritional supplements, and protein powder). It was also related to a higher intake from lunch and snack meals, the 'Super diet', desserts, and 'marzipan, candy, and nuts' in the intervention group compared to the control group. Intake from snacks; 'marzipan, candy, and nuts'; ice cream; and cream was positively correlated with energy and/or protein balance, whereas intake from 'juice, and soft drinks' was negatively correlated. These results are consistent with previous studies showing that fortified energy- and protein-rich foods and between-meal snacks can significantly improve energy and protein intake in patients.[79,81,106-109]

The essence of the food-sensory-quality-based nutritional care in the intervention group was to provide appropriate foods as per patients' individualised food sensory needs and motivation to eat. The patients in the control group were given general nutritional advice as well as daily attention from the research staff when their activity and dietary records were being checked. This was done in the control group to better ensure that the effect of the nutritional care provided to the intervention group related more so to the food-sensory-quality-based approach as opposed to nutritional counselling and/or extra attention provided to the patients. The current randomised control trial (*Study III*) was highly comparable to another Danish randomised controlled trial by Johansen et al.[39] since the studies involved the same hospital and used similar methods. Mean energy and protein balance in the intervention study of the current study was 12% and 13% higher, respectively, compared to Johansen et al.[39] The main difference between the nutritional care interventions between the two studies was the focus on food sensory quality in the current study. Furthermore, a nurse and a clinical dietitian provided the nutritional care in Johansen et al.,[39] whereas students directed by main investigator, provided the nutritional care in the current study. Therefore, a food-sensory-quality-based approach to nutritional care, as used in this study, appears to be successful at promoting intake in patients at nutritional risk.

6 Perspectives

6.1 Recommendations for food product development

There is tremendous opportunity afforded the hospital foodservice and food industry in terms of consumer-based innovation in development of food, beverages, and meals to promote intake in patients at nutritional risk. Suggestions for food product develop from this project are as follows:

- Develop meals, foods, and beverages with sensory properties that address the food sensory needs of patients segmented by their motivation to eat.
- Develop food and beverages that are associated with a positive post-ingestive response, e.g., stomach-settling, pleasantly satiating, thirst quenching, mouth cleansing, refreshing, and masking unpleasant tastes in the mouth.
- Develop familiar food and beverages that are adjusted to compensate for abnormal sensory perception and eating ability, e.g., increase moistness of foods for patients with dry mouth.
- Develop new food and beverages that address the food sensory needs of patients at nutritional risk, but for which there are limited expectations and therefore, less likelihood for disappointment.
- Develop food and beverages with optimal texture and consistency that facilitates ease of eating, i.e., easy to form a bolus and swallow.
- Develop meals in which all meal components have optimised nutrient density and composition whilst maintaining acceptable sensory quality.
- Develop food and beverages with optimal sensory qualities when served at room temperature.
- Develop meals comprised of multiple components and/or courses with varied sensory properties to compensate for early sensory-specific satiety.

6.2 Recommendations for clinical practice

The randomised controlled trial (*Study III*) demonstrated that individualised, food-sensory-quality-based nutritional care can lead to improvements in food intake as compared to usual nutritional care and advice. This suggests that more attention should perhaps be given to the food sensory quality of nutritional care provided for patients at nutritional risk. Furthermore, both the current qualitative study (*Study I*) and previous qualitative studies[67,68] have observed patients at nutritional eating by trial and error and expressing uncertainty of what to eat based on their current condition. Patients also stated that they would have appreciated more support and guidance from healthcare staff regarding appropriate food choices.[66,67] Healthcare staff have a potentially important role to play in guiding the food choices of patients at nutritional risk based on the patient's eating-related symptoms, food sensory needs, and motivation to eat.

6.3 Future research

A number of suggestions for food product development to promote intake in patients at nutritional risk are given in the previous section. It is important that newly developed food products can demonstrate a positive effect on outcome in a clinical setting. The randomised controlled trial (*Study III*) showed that measures of physiological function, e.g., handgrip strength, were sensitive to a food-based nutritional care intervention as based on rapid important within in a few days of starting nutritional care. Similar rapid improvements in handgrip strength were also found by Christie et al.,[21] but in a study of two-weeks parenteral nutrition in hospital. Most other randomised controlled trials investigating the effect of nutritional care intervention on handgrip strength[201] have been conducted in ambulatory patients over a longer period of time of at least a couple of months. The rapid improvement in handgrip strength in the current randomised controlled trial (*Study III*) is likely reflective of improvements in cellular function and metabolism,[202] whereas changes in handgrip strength shown in the studies over a longer period of time[201] are also likely reflective of changes in lean body mass. Handgrip strength is a sensitive, well validated method[203] that would be a useful to use as an outcome variable in future randomised controlled trial testing newly developed food products in patients at nutritional risk.

The questionnaire study (*Study II*) identified patterns of association between patient demographics, nutritional status, and the patient food choice questionnaire results using PCA. However, this study design was not conducive for investigating causal relationships between these variables. In the randomised controlled trial (*Study III*), it would have been ideal to assess multivariate interactions between variables. For example, interactions between the patient food choice questionnaire results, intake of specific foods items and meals, patient demographics, and nutritional status as related to study outcome, e.g., energy and protein balance could have been assessed. This was however limited by the small sample size of the study and otherwise, could have been accomplished using Partial Least Square (PLS) analysis in a large randomised controlled trial with at least double the sample size.

The cross-sectional questionnaire study (*Study II*) only investigated eating-related symptoms, food sensory needs, and motivation to eat at a single time point. On the other hand, food sensory quality as perceived by patients at nutritional risk was assessed in the qualitative study (*Study I*) in hospital and two weeks post-discharge. This allowed for investigation of changes over the course of illness and rehabilitation. This study found that some patients, who had experienced a long course of illness with numerous changes in their food sensory perception and eating ability, even had difficult remembering their original food preferences from prior to becoming ill. This finding highlights that it would be interesting to conduct longer longitudinal studies investigating the experiences and perceptions of food sensory quality in patients at nutritional risk in relation over the course of their illness.

The studies in this project were conducted in predominantly Danish patients. It is difficult to assess the international generalisability of the results due to the cultural homogeneity of the patients being studied. Food expectations are highly influenced by previous food experiences, which also relate to food culture, and have been found to be an important factor when assessing food quality.[195] It would therefore be interesting to repeat the qualitative and questionnaire studies (*Study I* and *II*) in other countries, especially with contrasting food cultures. This could help to determine the influence of food culture and common findings on the food sensory needs of patients at nutritional risk internationally.

7 Conclusions

An operational framework of food sensory quality to promote intake in patients at nutritional risk was developed based on qualitative and quantitative investigations (*Study I* and *II*) on food sensory quality as experienced and perceived by patients at nutritional risk. This framework was applied in a randomised controlled trial (*Study III*) of individualised, food-sensory-quality-based nutritional care in hospital patients at nutritional risk as compared to usual nutritional care and advice. The conclusions that can be drawn from these studies are as follows:

1. Patients' sensory perception and eating ability influenced their individualised food sensory needs regarding the appearance, aroma, taste, texture, temperature, and variety to promote intake. Motivation to eat, including: pleasure, comfort, and survival, provided an important context for patients' food choice. These observations were the basis for a model of food sensory quality to promote intake in patients at nutritional risk.

2. Patients could be segmented by their motivation to eat: pleasure *vs.* survival and contrasting food sensory needs: awakening appetite *vs.* facilitating intake, respectively.

3. Patients that forced themselves to eat were associated with lower energy and protein balance than in patients that enjoyed eating.

4. Individualised, food-sensory-quality-based nutritional care improved energy and protein intake in hospital patients at nutritional risk compared to usual nutritional care and advice.

5. Physiological function, measured by handgrip strength and reaction time, improved significantly already after a few days of food-based nutritional care in hospital patients at nutritional risk.

6. Improvements in physiological function, measured by handgrip strength and reaction time, were positively associated with energy and protein intake.

The framework generated by this project can be used to develop user-driven, innovative food and beverages to promote intake in patients at nutritional risk. Further studies are however needed to determine whether individual food products developed or improved based on these results can demonstrate an increase in food intake in patients at nutritional risk.

8 List of tables and figures

9 Abbreviations

ADL:	Activities of Daily Living
BIA:	Bioelectrical Impedance Analysis
BMI:	Body Mass Index (weight in kg / height in m^2)
C:	Capacitance
EFG:	ElectroFluidGraph
HGS:	Handgrip Strength
IQR:	Interquartile Range
GLM:	Generalised Linear Models
LOS:	Length of Stay
PLS:	Partial Least Square
NRS-2002:	Nutritional Risk Screening 2002[40]
NS:	Not Significant
PA:	Phase Angle
PC:	Principal Component
PCA:	Principal Component Analysis
RT:	Reaction Time
R:	Resistance
SF-36:	Short Form 36 health survey questionnaire
SD:	Standard Deviation
VAS:	Visual Analogue Scale
Xc:	Reactance

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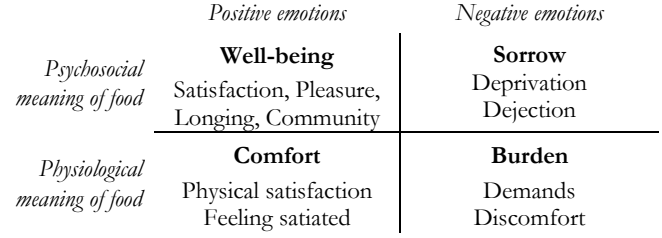
11 Appendices

Appendix 1: Qualitative studies on patients' eating-related problems

Table 8 – Qualitative studies on patients' eating-related problems.

Study methods	Summary of results
Olsson et al.[65] 2002, Sweden Appetite, hunger, changes in weight and intake 3-months post-gastrectomy due to tumour. (N=15)	1) 'Struggle to eat and drink' (e.g., 'lack of appetite and hunger', self-forced eating, 'difficulty in eating and drinking', frequently eating smaller portions, 'feelings of nausea', 'fight and adaption' to maintain previous eating patterns). 2) 'Bodily estrangement' (e.g., 'differences in sensation': taste changes, which caused uncertainty; 'difference in appear': weight loss, changed body image). 3) 'Nutritional treatment and regimes' (e.g., 'dependency and adaption' to nutrition regimens; 'isolation and encroachment' and 'physical discomfort' from enteral and parenteral nutrition).
Perry et al.[56] 2004, Sweden Eating-related experiences 6-months post-stroke. (N=113)	▪ Patients were affected by upper limb motor/sensory (75%), visual/ perceptual (26%), communication (27%), lip closure (10%), chewing (18%) and swallowing (19%) impairments or needed prompting at mealtimes (4%). ▪ Fatigue was common, affecting food purchase and preparation and appetite. ▪ Eating impairments affected 66% of patients and had inconsistent effects depending on the patient's reaction, e.g., level of embarrassment from eating. ▪ Modified consistency fluids were universally disliked and avoided and oral nutritional supplements were associated with bloating and overly sweet. ▪ Maintaining normal appearances at mealtimes was important. ▪ Eating functioned as an index of progress.
Jacobsson et al.[69] 2004, Sweden Experience of food and food intake in ambulatory and hospital patients with heart failure. (N=11)	A model of factors influencing experiences of food and food intake was developed: 

Study methods	Summary of results
Orrevall et al.[66] 2004, Sweden Path from oral nutrition to home parenteral nutrition in advanced cancer patients. (N=24) 13 patients 11 family members	▪ Initially unaware of or positive for weight loss, which was gradually replaced by a fear of death by starvation. ▪ Inability to eat due to nausea, loss of appetite, weakness, difficulty in swallowing, gastrointestinal dysfunction, and/or changes in sense of taste and smell (often multifactorial). ▪ Meals as a source of worry and despair and no longer pleasurable. ▪ Family members struggled to help patients to eat (e.g., strategies included cooking special dishes, serving food differently, and nutrient fortification, eventually to no avail; control of the patient's food intake by family; fear that nagging to eat may further worsen intake). ▪ Lack of involvement of healthcare staff in nutritional care (e.g., physicians lack of focus on nutritional issues, no inquiry about weight changes or food intake, lack of action in response to low food intake, fasting for examinations, lack of access to suitable foods, marginal role of dietitian, lack of follow-up, advice common sense or contradictory). ▪ Lack of success from oral nutritional supplements (e.g. used for a short period, unable to drink due to the smell and taste; resulting in stomach pains, nausea or vomiting).
Shragge et al.[66] 2007, Canada Emotional and social impact of appetite loss and strategies to compensate for reduced intake in advanced cancer patients with anorexia. (N=9) 15 interviews	An adaption of shifting to conscious control of eating enabled patients to compensate for decreased food intake. This process included the following four stages: Stage I: Recognising the changes: eating-related symptoms typically began insidiously, but recognition of the gravity of these changes triggered the process. Stage II: Harnessing the motivation to eat: 'recasting eating as a necessity' for survival and 'reframing the objectives of eating' in terms of rehabilitation, body weight, and strength. Stage III: Working around the limitation: limiting the physical distress caused by eating through 'finding what works' as per ones eating-related symptoms and 'drawing a line' to stop eating under physical distress, especially due to nausea and anticipated emesis. Stage IV: Sustaining the shift: control of eating was maintained by 'going through the motions', 'lowering expectations', 'putting it into perspective' and 'monitoring changing capabilities' regarding eating and food intake.

Study methods	Summary of results
Bernhardson et al.[67] 2007, Sweden Chemotherapy-induced taste and smell changes in cancer patients with monthly follow-up interviews until chemosensory changes ceased. (N=21) 75 interviews	▪ Great individual variation in pattern, intensity and impact of taste and smell changes (e.g., different descriptors used, duration from 0.5 to 14 weeks). ▪ Typically a gradual deterioration and improvement of changes; difficulty distinguishing between taste and smell changes; discussed unpleasant tastes. ▪ Interrelationship between eating-related symptoms (e.g., taste changes lowering appetite, sensitivity to smells resulting in nausea, taste changes related to dry mouth/coating on the tongue). ▪ Taste changes: always viewed as unpleasant, related to all or specific foods and altered thresholds, daily variation, and mostly related to sweet or salt. ▪ Olfactory changes: typically negative, but not always; related to altered threshold to cooking odours, perfumes and cleaning products. ▪ Evoked negative emotions, decreased satisfaction or comfort from food, made food choices and ability to assess freshness and spoilage difficult. ▪ Strategies to cope included testing food for tolerance, eating familiar meals, avoiding dishes with complex seasoning or sauces, giving up on expectations by choosing neutral foods, avoiding areas with problematic odours, acceptance of the changes and relying on smell and taste memories. ▪ Suggestions from healthcare staff were limited and not always helpful.
Holst et al.[70] 2010, Denmark Experience of undernutrition in hospital-admitted gastroenterology patients at severe nutritional risk. (N=12)	1) 'Physical and psychological impact' was recognised after noticeable weight loss and related was to illness, pain, weakness, lack of concentration, poor mood, apathy and self-pity. 2) 'Reasons for not eating/impact of medication': lack of appetite, pain, bad taste, nausea, and side-effects of medication, such as lowering appetite and negative taste changes. 3) 'Motivation and expectation to staff': two groups were identified as 'active' or 'passive' as per their respectively high or low motivation and engagement in their nutritional care 4) 'The role of others': relatives helped with food and encouragement to eat, which was appreciated, but sometimes overbearing; fellow patients had a mixed impact on eating.

Appendix 2: Patient food choice questionnaire in Danish

Jeg nævner nu en række symptomer.
I hvilken grad oplever du følgende symptomer?

Symptomer	**Svarkategorier**			**Kommentarer**
Manglende appetit (Min appetit er nedsat.)	Slet ikke	Noget	Meget	_____
Tidlig mæthed (Jeg bliver hurtigt mæt.)	Slet ikke	Noget	Meget	_____
Kvalme	Slet ikke	Noget	Meget	_____
Opkastning	Slet ikke	Noget	Meget	_____
Mundtørhed / manglende spyt	Slet ikke	Noget	Meget	_____
Smerter eller ubehag i munden	Slet ikke	Noget	Meget	_____
Smerter eller ubehag i halsen	Slet ikke	Noget	Meget	_____
Smerter eller ubehag i maven	Slet ikke	Noget	Meget	_____
Problemer med at tygge	Slet ikke	Noget	Meget	_____
Problemer med at synke	Slet ikke	Noget	Meget	_____
Diarre	Slet ikke	Noget	Meget	_____
Forstoppelse	Slet ikke	Noget	Meget	_____
Behov for hjælp med at spise	Slet ikke	Noget	Meget	_____
Madallergi eller intolerans	Slet ikke	Noget	Meget	_____
Hvis ja, hvilket:_____				
Smagsændringer	Slet ikke	Noget	Meget	_____
Hvis ja, hvilket:_____				

Jeg vil nu læse nogle udsagn om dine måltidsoplevelser og -præferencer.
For hvert udsagn skal du blot svare hvor enig eller uenig du er med hvert udsagn for dit vedkommende ifølge HVORDAN DU HAR DET LIGE NU.

	Spørgsmål	Svarkategorier				
1	Jeg foretrækker at spise mad, som jeg genkender.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
2	Jeg foretrækker mad, der er pyntet med lidt grønt eller forskellige farver.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
3	Jeg foretrækker, at mad (fx kød, kartofler, grøntsager, sovs) ikke er blandet sammen.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
4	Jeg foretrækker enkel mad, fx uden så meget pynt og med få ingredienser.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
5	Jeg foretrækker små anretninger.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
6	Det er vigtigt, at maden ser appetitlig ud for at jeg vil spise det.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
7	Duften af nogle madvarer, fx. ristet eller friskbagt brød, virker appetitvækkende og fremmer min lyst til at spise.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
8	Duften af mad kan give mig, fx kvalme, og nedsætter min lyst eller evne til at spise.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
9	Jeg bryder mig ikke om kunstig smag som, fx smagen i kommercielle ernæringsdrikke, proteinberiget is.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
10	Det er vigtigt at kunne smage råvarerne, fx tomat i tomatsuppe.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
11	Jeg går efter syrlig smag som fx i yoghurt, koldskål, agurke salat, altså mad- og drikkevare med syrlig smag.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
12	Når jeg spiser et fedtrigt måltid, er det vigtigt at spise noget friskt og syrligt ved siden af fx agurke salat, rødbeder, asier.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
13	Jeg går efter fx ost, pølser, bouillon, der "smager af noget".	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
14	Jeg går efter saltet mad som fx chips, peanuts, saltkiks.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
15	Jeg går efter søde sager som fx kager, wienerbrød, slik, desserter.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
16	Jeg foretrækker mad med forskellige slags smag, fx surt, sødt, salt.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig

	Spørgsmål	Svarkategorier				
17	Mine lyst til forskellige slags smag ændrer sig hele tiden.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
18	Jeg foretrækker mad med mild/neutral smag.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
19	Krydret smag nedsætter min lyst eller evne til at spise.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
20	Det er vigtigt, at maden smager som jeg foretrækker for at jeg vil spise det.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
21	Jeg går primært efter mad, der er nemt at spise, dvs. det skal ikke tygges så meget og glider nemt ned.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
22	Jeg spiser kun blød eller flydende mad.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
23	Jeg foretrækker mad, der serveres med meget sovs, dressing, eller noget lignende, der giver væde.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
24	Jeg oplever nogle gange at maden vokser i munden, hvilket nedsætter min lyst eller evne til at spise.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
25	Jeg oplever nogle gang at maden, fx mejeriprodukter, efterlader en hinde i munden, hvilket nedsætter min lyst eller evne til at spise.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
26	Jeg foretrækker let mad, fx med mange grøntsager, frem for fed mad, fx. med meget fløde, smør, osv.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
27	Jeg kan lide fornemmelsen af at spise noget sprødt eller knasende, fx frisk grøntsager, bacon, ristet brød, knækbrød, altså sprødt eller knasende madvare.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
28	Jeg foretrækker at spise mad med forskellige konsistenser som fx tarteletter med høns i asparges, hvor tarteletten er sprødt og fyldet er blødt.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
29	Jeg synes, at min krop trænger til mere solid kost, fx rugbrød med pålæg frem for suppe til frokost.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
30	Jeg går efter mad- og drikkevarer, der er forfriskende og læskende som fx frisk frugt og grøntsager, sodavandsis, cola, altså forfriskende og læskende mad- og drikkevare.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
31	Jeg går efter mad- og drikkevarer, der giver en god mavefornemmelse som fx havregryn eller -grød, yoghurt, frugt, fisk, altså mad- og drikkevare, der giver en god mavefornemmelse.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
32	Det er vigtigt, at madens konsistens, dvs. hvor fast, blødt, flydende osv. er som jeg foretrækker for at jeg vil spise det.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig

	Spørgsmål	Svarkategorier				
33	Jeg spiser og drikker langsomt, det kan gå ud over temperaturen, og så mister jeg lysten til at fortsætte.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
34	Jeg foretrækker retter, som er afvekslende mht. udseende, smag, konsistens, temperatur, osv.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
35	Jeg mister hurtigt lysten til at spise eller drikke noget bestemt, men kan måske fristes til at spise eller drikke noget andet.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
36	Jeg foretrækker at spise varieret og noget forskelligt hver dag for at fremme min lyst til at spise.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
37	Det er svært at vide på forhånd, hvad jeg har lyst til at spise fra måltid til måltid.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
38	Jeg har svært ved at finde mad som min krop kan tåle.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
39	Jeg spiser nogenlunde det samme ting hver dag.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
40	Jeg spiser kun, når jeg er sulten.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
41	Jeg nyder min mad.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
42	Det er vigtigt for mig, at jeg nyder min mad for at jeg vil spise det.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
43	Jeg går mest efter mad, som jeg tror er sundt for min krop.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
44	Jeg vælger mest mad- og drikkevarer ud fra anbefalingerne fra mine læger, sygeplejersker, diætister, osv.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
45	Jeg tvinger ofte mig selv til at spise.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig
46	Jeg spiser for at klare min sygdom.	Helt enig	Delvist enig	Hverken enig eller uenig	Delvist uenig	Helt uenig

Appendix 3: Patient food choice questionnaire results

Table 9 – Patient food choice questionnaire results.

Statement	'Fully disagree' [a]	'Partially disagree' [a]	"Neither agree nor disagree' [a]	"Partially agree' [a]	'Fully agree' [a]
Appearance					
Q1) I prefer to eat food that is familiar.	20 (10%)	26 (13%)	11 (6%)	35 (18%)	108 (54%)
Q2) I prefer food that is garnished with greens or different colours.	37 (19%)	21 (11%)	11 (6%)	36 (18%)	95 (48%)
Q3) I prefer that my foods, such as meat, potatoes, sauce and so forth, are not mixed together.	40 (20%)	15 (8%)	15 (8%)	23 (12%)	107 (54%)
Q4) I prefer simple food that does not have much garnishing and that is made of few ingredients.	34 (17%)	32 (16%)	16 (8%)	42 (21%)	76 (38%)
Q5) I prefer small portions.	13 (7%)	4 (2%)	10 (5%)	23 (12%)	150 (75%)
Q6) It is important that my food appears appetising in order for me to eat it.	4 (2%)	4 (2%)	4 (2%)	17 (9%)	171 (86%)
Aroma					
Q7) The aroma of some foods, such as fresh or toasted bread, is appetising and promotes my desire to eat.	20 (10%)	10 (5%)	12 (6%)	26 (13%)	132 (66%)
Q8) The aroma of food can give me, e.g., nausea, and decrease my desire or ability to eat.	66 (33%)	9 (5%)	13 (7%)	39 (20%)	73 (37%)
Taste					
Q9) I do not care for artificial flavours, such as the flavour of commercial nutritional supplements.	33 (17%)	10 (5%)	14 (7%)	31 (16%)	112 (56%)
Q10) It is important to be able to taste the raw ingredients, such as the tomato in tomato soup.	6 (3%)	7 (4%)	2 (1%)	31 (16%)	154 (77%)
Q11) I prefer sour foods, such as in yoghurt, sour drinks, pickles, etc.	53 (27%)	24 (12%)	18 (9%)	42 (21%)	63 (32%)
Q12) When I eat a fat-rich meal, it is important to eat something fresh and sour on the side, such as pickled cucumber or pickled beetroot.	30 (15%)	15 (8%)	18 (9%)	35 (18%)	102 (51%)
Q13) I prefer foods, such as cheese, sausages and bouillon, which are more flavourful.	24 (12%)	21 (11%)	8 (4%)	34 (17%)	113 (57%)
Q14) I prefer salty food, such as chips, peanuts, saltines, etc.	99 (50%)	38 (19%)	5 (3%)	29 (15%)	29 (15%)
Q15) I prefer sweet foods, such as cakes, pastries, candy, desserts, etc.	83 (42%)	27 (14%)	8 (4%)	37 (19%)	45 (23%)
Q16) I prefer foods with different tastes, such as sour, sweet, salt and so on.	7 (4%)	13 (7%)	26 (13%)	47 (24%)	107 (54%)
Q17) My desire for different tastes changes all the time.	78 (39%)	22 (11%)	6 (3%)	40 (20%)	54 (27%)
Q18) I prefer food with a mild / neutral taste.	82 (41%)	28 (14%)	12 (6%)	39 (20%)	39 (20%)
Q19) Spicy flavours decrease my desire or ability to eat.	76 (38%)	23 (12%)	10 (5%)	41 (21%)	50 (25%)

Statement	'Fully disagree' [a]	'Partially disagree' [a]	"Neither agree nor disagree' [a]	"Partially agree' [a]	'Fully agree' [a]
Q20) It is important that my food tastes as I prefer in order for me to eat it.	8 (4%)	15 (8%)	6 (3%)	38 (19%)	133 (67%)
Texture and consistency					
Q21) I prefer mostly food that is easy to eat, i.e., easy to chew and swallow.	63 (32%)	26 (13%)	4 (2%)	25 (13%)	82 (41%)
Q22) I eat only soft or fluid foods.	124 (62%)	19 (10%)	5 (3%)	24 (12%)	28 (14%)
Q23) I prefer food that is served with lots of sauce, dressing or something similar that gives moisture.	43 (22%)	32 (16%)	9 (5%)	42 (21%)	75 (38%)
Q24) I experience sometimes that food expands in my mouth, which decreases my desire or ability to eat.	59 (30%)	22 (11%)	4 (2%)	47 (24%)	68 (34%)
Q25) I experience sometimes that foods, such as dairy products, leave a film in my mouth, which decreases my desire or ability to eat.	96 (48%)	17 (9%)	8 (4%)	36 (18%)	43 (22%)
Q26) I prefer 'light foods', such as with lots of vegetables, as opposed to fatty food with lots of cream, butter and so on.	43 (22%)	18 (9%)	17 (9%)	35 (18%)	87 (44%)
Q27) I like the feeling of eating foods that are crispy or crunchy, such as fresh vegetables, bacon, toast, or crackers.	35 (18%)	24 (12%)	10 (5%)	36 (18%)	95 (48%)
Q28) I prefer to eat foods with varying texture such as pot pie in which the pastry is crunchy and the filling is soft.	18 (9%)	9 (5%)	14 (7%)	40 (20%)	119 (60%)
Q29) I feel that my body needs a more solid diet, such as rye bread and cold cuts as opposed to soup for lunch.	41 (21%)	22 (11%)	28 (14%)	39 (20%)	70 (35%)
Q30) I prefer food and drink that is refreshing and thirst quenching, such as fresh fruit and vegetables, popsicles, cola, etc.	14 (7%)	15 (8%)	7 (4%)	42 (21%)	122 (61%)
Q31) I prefer food and drink that is pleasantly satiating, such as oat porridge, yoghurt, fruit, fish, etc.	20 (10%)	17 (9%)	13 (7%)	39 (20%)	111(56%)
Q32) It is important that the consistency of my food (i.e., how solid, soft or fluid my food is), is as I prefer in order for me to eat it.	13 (7%)	16 (8%)	11 (6%)	49 (25%)	111(56%)
Temperature					
Q33) I eat and drink slowly, which can compromise the temperature and my desire to continue eating or drinking.	88 (44%)	26 (13%)	6 (3%)	32 (16%)	48 (24%)
Variety					
Q34) I prefer dishes that are varied in terms of taste, texture, consistency, temperature and so on.	17 (9%)	14 (7%)	15 (8%)	38 (19%)	116(58%)
Q35) I quickly lose the desire to eat or drink particular things, but I can perhaps be tempted to eat or drink something else.	56 (28%)	25 (13%)	12 (6%)	55 (28%)	52 (26%)

Statement	'Fully disagree' [a]	'Partially disagree' [a]	"Neither agree nor disagree' [a]	"Partially agree' [a]	'Fully agree' [a]
Q36) I prefer to eat varied and different foods daily in order to increase my desire to eat.	28 (14%)	21 (11%)	10 (5%)	35 (18%)	106 (53%)
Q37) It is difficult to know what I would like to eat from meal to meal.	29 (15%)	11 (6%)	7 (4%)	35 (18%)	118 (59%)
Q38) I have difficulty finding food that my body can tolerate.	144 (72%)	14 (7%)	6 (3%)	13 (7%)	23 (12%)
Q39) I eat mostly the same things from day to day.	51 (26%)	16 (8%)	12 (6%)	61 (31%)	60 (30%)
Motivation to eat					
Q40) I eat only when I am hungry.	57 (29%)	30 (15%)	5 (3%)	30 (15%)	78 (39%)
Q41) I enjoy my food.	43 (22%)	22 (11%)	6 (3%)	51 (26%)	78 (39%)
Q42) It is important for me that I enjoy my food in order for me to eat it.	19 (10%)	27 (14%)	6 (3%)	49 (25%)	99 (50%)
Q43) I strive to eat foods, which I believe are healthy for my body.	51 (26%)	21 (11%)	9 (5%)	36 (18%)	83 (42%)
Q44) I choose food and drinks based on recommendations from my doctors, nurses, dietitians and so on.	62 (31%)	26 (13%)	19 (10%)	32 (16%)	61 (31%)
Q45) I often force myself to eat	62 (31%)	13 (7%)	5 (3%)	40 (20%)	80 (40%)
Q46) I eat to overcome my illness.	28 (14%)	10 (5%)	7 (4%)	33 (17%)	122 (61%)

[a] Results expressed as N (%). (N=200)

Appendix 4: Paper I

Food for patients at nutritional risk: a model of food sensory quality to promote intake

Food for patients at nutritional risk: a model of food sensory quality to promote intake

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Short title: Food for patients at nutritional risk

Non-standard abbreviations: NRS-2002: Nutritional Risk Screening-2002; VAS: visual analogue scale, IQR: interquartile range.

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Abstract

Background & Aims: The aim was to investigate food sensory quality as experienced and perceived by patients at nutritional risk within the context of establishing a framework to develop foods to improve food intake.

Methods: Patients at nutritional risk (NRS-2002; food intake ≤75% of requirements) were observed at meals in hospital (food choice, hunger/fullness/appetite scores). This was followed by a semi-structured interview based on the observations and focusing on food sensory perception and eating ability as related to food quality. Two weeks post-discharge, a 3-day food record was taken and interviews were repeated by phone. Interviews were transcribed, coded, and analysed thematically.

Results: Patients (N=22) from departments of gastrointestinal surgery, oncology, infectious medicine, cardiology, and hepatology were interviewed at meals (N=65) in hospital (82%) and post-discharge (18%). Food sensory perception and eating ability dictated specific food sensory needs (i.e., appearance, aroma, taste, texture, temperature, and variety defining food sensory quality to promote intake) within the context of motivation to eat including: pleasure, comfort, and survival. Patients exhibited large inter- and intra-individual variability in their food sensory needs.

Conclusions: The study generated a model for optimising food sensory quality and developing user-driven, innovative foods to promote intake in patients at nutritional risk.

Keywords: disease-related malnutrition in hospital, qualitative, food sensory quality, low food intake, low appetite, early satiety.

Introduction

Undernutrition affects about a third of patients in hospital.[1] If nutritional therapy is not adequately provided, these patients have a higher risk of diminished physiological function, complications, longer length of hospital stay, decreased quality of life, and mortality.[1,2] Ordinary food is recommended as the first choice to prevent or correct undernutrition and the majority of patients at nutritional risk rely solely on food intake to meet their nutritional requirements.[3] However, in spite of sufficient food provisions, numerous studies have highlighted the problem of inadequate dietary intake in hospitalised patients.[4,5] This then leads to poorer clinical outcome in these patients[6,7] and large amounts of food waste.[8]

A large, comparative study on food intake in hospital found that nutritional needs were covered in only about a third of patients in 1999, which was unchanged in 2008 despite hospital wide initiatives to improve food service practice, e.g., declaring patient's alimentary rights, applying food recommendation, patient-self menu selection and change in meal times and cooking.[5] Low meal quality, as evaluated by patients on a 10-point visual analogue scale (VAS), was associated with low nutritional intake. A questionnaire with four predetermined categories showed in 2008 that patients that did not eat all of their food gave the following reasons: absence of menu selection (32%), inadequate taste (25%), inadequate cooking (10%) and/or inadequate mealtime (5%). This study demonstrates the challenge of improving hospital food intake. In contrast, two intervention studies[9,10] have shown that individual nutritional care in hospital, consisting predominantly of ordinary food, can significantly improve intake and clinical outcome. These studies involved a dedicated individual[9] or team[10] that provided nutritional care for the intervention group. The studies provided very limited information on the characteristics of the ordinary food that helped to improve intake. Perhaps, hospital food prepared in accordance with patients' expectations and eating ability could lead to improved intake with a less costly staff requirement.

Few studies have prospectively investigated mediating factors affecting food intake in patients. One such study by Paquet et al.[11] in elderly patients reported that energy and protein intake was positively correlated to patient assessed 'food sensory quality', but not to 'food service quality' or any measure of satisfaction. The study defined 'perceived quality' by these 2 components: food sensory quality (i.e., tastefulness, appropriateness of food temperature and texture, palatability), and food service quality (i.e., staff attitude, service timeliness, duration, feeding assistance, sitting position). 'Satisfaction' was measured by satisfaction with the: 'service' (i.e., interaction with staff), 'food' and 'overall' (i.e., meal as a whole).

Food sensory quality has been suggested to comprise colour and appearance, odour, taste, textural properties, tactile properties, and sound of food.[12] Considering the potentially large complexity of food sensory quality studies in a clinical setting, a qualitative study approach may be an operational starting point since it is exploratory and flexible in nature and produces in-depth, descriptive data on the human experience from which new hypotheses can be generated. Qualitative methods have been used in specific patient groups (e.g., cancer,[13-15] gastrectomy,[16] heart failure,[17] and severely undernourished patients[18]) to describe the eating-related challenges faced by patients, including: inability to eat and lack of attention from hospital staff;[13] highly variable experiences of taste and smell changes;[14] struggles to eat and bodily estrangement;[16] feelings of burden and sorrow in relation to eating;[17] shift to conscious control over eating;[15] and passive *vs.* active patients.[18] Also, patients were found to use a trial and error approach to find suitable food.[14,15] All of these studies focused on describing eating problems, rather than aiming at possible solutions to promote food intake in patients at nutritional risk.

In light of this, a systematic investigation of how food sensory quality can be optimised for patients at nutritional risk is needed. This study aimed at exploring food sensory quality as experienced and perceived by patients at nutritional risk during various meals. It was the initial phase of a project aimed at establishing a framework for developing

appetising, energy- and protein-rich foods to promote intake in patients at nutritional risk and, in particular, served as the basis for a quantitative questionnaire study for further confirmation of the results.

Materials and Methods

Participants

Study participants were recruited from medical and surgical units in the departments of oncology, gastrointestinal surgery, infectious medicine, cardiology, hepatology, and rheumatology at Copenhagen University Hospital (Rigshospitalet). All newly admitted adult patients (≥ 18 years old) who were at-risk according to nutritional risk screening (NRS-2002 ≥ 3), had an inadequate food intake (i.e., below 75 % of usual intake in the last week), were allowed to eat orally without anatomical hindrances, and did not rely on enteral and/or parenteral nutrition were considered for inclusion in the study. Exclusion criteria were: one-day admissions, inability to communicate coherently, lack of consciousness, or language barriers. Patients not found at nutritional risk were rescreened by NRS-2002 on a weekly basis and reassessed for inclusion in the study. Recruitment was done consecutively until a suitable patient was found and completed the study. Patients that met the inclusion and exclusion criteria were invited to participate in the study by the first author and required to provide informed consent. The study protocol was approved by the local Biomedical Ethics Committee for The Capital Region of Denmark.

Recruitment aimed at including a diverse sample of patients in terms of age, sex and medical versus surgical diagnoses (Table 1). Patients were included in the study over a period of three months from June to August 2008. Sample size was determined to optimise diversity and based on saturation of the data, i.e., when additional observations and interviews provided diminished returns in terms of new information.

Hospital setting and foodservice

Rigshospitalet is an acute-care, tertiary hospital with 1,200 beds divided into units comprised of 15–20 beds. All departments had a common dining room apart from the infectious medicine department, which was attributed to isolation procedures. Food is prepared centrally in the hospital kitchen by cook-chill, cook-freeze and cook-serve. Three main meals are served daily, buffet style and based on a 5-week menu rotation. The three main diet types include the 'hospital diet' with higher energy and protein density than the 'normal healthy diet', and 'vegetarian diet'. Breakfast includes a standard assortment of e.g., yogurts, cereals, porridges, bread, cheeses, nut / sweet spreads, and/or fruit. Lunch comprises of open-faced sandwiches with a choice of 4 varying toppings in addition to a standard topping selection as well as a soup and an entrée dish of the day. Supper consists of a choice of 3 different menus followed by dessert and/or fruit porridge. The main meals are expected to cover about two-thirds of requirements. The remaining third of requirements are fulfilled by snacks, drinks, and frozen, microwaveable meals available from small kitchens on the units and nutritional supplements. Patients at nutritional risk can be referred to a dietitian and, if deemed relevant, prescribed the "Super diet", which is an à la carte menu for patients at nutritional risk. The "Super diet" was developed with the aim of optimising energy and protein density, quality and selection of meals. The "Super diet" includes a selection of breakfast items, sandwiches, various cold and warm lunch and supper dishes, side dishes, desserts and snacks. Patients on the "Super diet" are given the option to order menu items directly from the kitchen by telephone or assisted by the nursing staff and are followed by a dietitian. Patients can also be referred to modified consistency / therapeutic diets or ethnic menus.

Data collection

Information was collected on patients' age, gender, diagnoses, length of stay and discharge destination. All patients were of Danish origin apart from three immigrant patients originally from Poland, Greece, and Indonesian, but who had been living in Denmark for a number of years. Nutritional risk was determined by NRS-2002[19] in which the nutritional risk score is calculated by adding the 'Nutritional Score' of 0 to 3 to the 'Severity of Disease Score' of 0 to 3 plus a score of 1 for patients older than 70 years. The 'Nutritional Score' is defined by adequacy of food intake in the previous week assessed as quartiles of requirement, presence of ≥ 5% weight loss in a specified period within the last three months and body mass index. Body weight was obtained by weighing and height was obtained from the patients. The 'Severity of Disease Score' is meant to reflect increases in protein requirements caused by stress metabolism. It is defined by the condition of the patient: chronically ill, but ambulatory; confined to bed due to illness; or in intensive therapy. A total score of 3 or more indicates risk for undernutrition that should be treated.[19]

Patients were observed during meals in hospital followed by semi-structured interviews conducted by the first author, a graduate student in clinical nutrition and registered dietitian from outside of the hospital. Depending upon their availability and length of stay, patients were observed and interviewed at the three main meals including breakfast, lunch and supper and, if the opportunity arose, during snacks. Patients were instructed to eat wherever and whatever they preferred and were welcome to chat with the interviewer during the meal. The interviewer did not give any recommendations regarding meals during observations and interviews. However, out of ethical responsibility, nutrition related advice was given following the interviews to those that had questions or displayed an inappropriate understanding of nutrition.

Meal observations in hospital included photos of initial and remaining food and drinks comprising the meals, timing and duration of meals, handwritten notes on comments during meals and eating behaviour, and a description of the eating environment and foodservice. Patients also rated their hunger and fullness on 150-mm VAS directly before and after meals and VAS ratings of the appetising effect of the meal once finished eating. VAS questions included: "How hungry do you feel now?" ("not hungry at all" to "very hungry"), "How full do you feel now?" ("not full at all" to "very full"), and "How appetising did you find the meal?" ("not stimulating at all" to "very stimulating")[20] as based on Yeomans et al.[21] Amount of meal eaten was assessed visually[22] from the initial photo of the meal served compared to a final photo of the meal plate waste. Percent intake quartiles[22] were calculated by the amount of meal eaten as the percent of a meal portion set at 2000 kJ / meal and used to group patients based on their intake. Interviews were conducted directly following the meal. Within the first couple of weeks following discharge from the hospital to home, a 3-day food record and photos of meals were taken by the patients using a disposable camera and sent to the investigator by mail. Data on energy and protein content of foods was taken from the Master Cater System (Anova Data, Holte, Denmark). Interviews based on these records were repeated by phone approximately two weeks post-discharge. Conducting interviews both in-hospital and post-discharge allowed for a more nuanced investigation of patients' perception of food sensory quality since it was not limited to a specific eating environment and food supply. It also allowed for a longer follow-up period in which changes over the course of the illness and rehabilitation could be investigated.

The interviews were initiated based on the meal observations or food records and started with a general, open-ended question of what the patient thought of the food that they had eaten. A semi-structured interview guide was then followed and focused the interview on the patient's experiences and preferences regarding food sensory quality including the appearance, taste, aroma, texture, temperature and variety of the meal that was eaten. These topics were then discussed in a broader context of the patient's previous food sensory experiences during the course of their illness as

compared to when healthy and their usual eating routine. Changes in the patient's sensory perception and/or eating ability (e.g., low hunger and early satiety (VAS ratings), taste changes, difficulty chewing / swallowing, etc.) was also discussed in relation to their perception of food sensory quality. Emerging themes (i.e., newly identified topics found to be relevant to the study's aim) were incorporated in the interview guide and discussed with subsequent participants. Also, other meal related issues were discussed if mentioned by the patient (e.g., social aspects, serving environment and access to food), although this was not the primary focus of the interview.

Analysis

Interview audio recordings were transcribed verbatim by the first author or an undergraduate research assistant, whose work was reviewed for accuracy by the first author. A total of 14.4 hours of interview recordings corresponding to a median (interquartile range (IQR)) of 12.9 (7.8 – 16.6) minutes per interview were analysed. A thematic coding framework was developed based on the interview guide (i.e., changes in food sensory perception and eating ability, food sensory quality properties, and emerging themes). Emerging themes included the nature of the patient's motivation to eat; relationship to and understanding of food and nutrition, menu choice and meal suggestions from others, nutritional supplements, and the "Super diet". All transcripts were coded by the first author using qualitative data analysis software, ATLAS.ti 5.0 from which it was possible to extract reports of text excerpts for each code. Codes for which there were numerous related text excerpts were sub-coded (e.g., specific tastes, textures/consistencies, foods) and grouped as positive or negative statements to further facilitate analysis of the data.[23] An analysis summary document organised according to the thematic coding framework was drafted by the first author. This process was done in conjunction with continual referral to the full interview transcripts, meal observations, and/or patient characteristics to provide context to the specific text excerpts.

The analysis summary document was reviewed, discussed, and commented on by all authors, who provided interdisciplinary perspectives on the themes from the areas of dietetics, sociology of food, food sensory science, gastronomy and clinical nutrition medicine. A focus group interview was also conducted with an interdisciplinary group of colleagues that worked with patients at nutritional risk including three clinical dietitians, a clinical nurse specialist and a foodservice employee that helped develop the hospital's "Super diet". The analysis summary was presented to the focus group by the first author and participants who shared their feedback and interpretations of the results.

Illustrative quotations were extracted from the interview transcriptions and translated from Danish to English by the first author, a native English speaker fluent in Danish. Quotes are written in italics, … indicates omitted words, and words in square brackets have been added for clarity. Descriptive statistics of continuous data is typically presented as median (IQR) in accordance with a non-normal distribution. VAS scores are reported as a relative percent.[24]

Results

There were included 11 male patients (median 56 years, range 24–74 years) and 11 female patients (median 42 years, range 22–72 years) in the study (Table 1) and 14 patients declined to participate. Out of a total of 65 interviews, 53 interviews were conducted during the hospital admission in conjunction with meal observations of breakfast (n=14), lunch (n=19), a snack (n=2), and supper (n=18) and 12 interviews were conducted two weeks post-discharge.

Meal observations

Meals were eaten in the common dining room (n=23), sitting up in bed (n=11), at the edge of the bed (n=9), at a table in the patient's room (n=9), or in the corridor (n=1). The majority of patients chose their meal from the regular buffet menu (n=44), whereas the remainder of patients ordered their meal à la carte from the "Super diet" menu (n=5), or had their meal brought from home (n=2), or as take-away from a local restaurant (n=2).

Table 1 – Patient characteristics (N = 22).

	N (%)
Age, years	
20-39	6 (27)
40-59	8 (36)
≥ 60	8 (36)
Gender	
Male / Female	11 (50) / 11 (50)
Department	
Gastrointestinal surgery	8 (36)
Oncology	6 (27)
Infectious medicine	6 (27)
Cardiology	1 (5)
Hepatology	1 (5)
Medical / Surgical	17 (77) / 5 (23)
Malignant / Benign	14 (64) / 8 (36)
Primary diagnosis [a]	
Cancer	5 (23)
Infection	5 (23)
Abdominal surgery	5 (18)
G.I.-disorders / abdominal pain	4 (9)
Hepatic cirrhosis	1 (5)
Ischemic heart disease	1 (5)
Observation	1 (5)
NRS-2002	
Rescreening [b]	5 (23)
Body mass index, kg/m^2	20.2 (19.1 – 23.1) [c]
Weight loss ≥ 5% [d]	9 (41)
Intake 0-25% [e]	2 (9)
Intake 25-50% [e]	18 (82)
Intake 50-75% [e]	2 (9)
Length of stay, days	14.5 (8.0 – 21.0) [c]
Discharge destination [f]	
Home	19 (86)
Hospital	3 (14)

[a] Diagnoses were entered from a list of diagnosis categories based on Sorensen et al.[1]
[b] Patients assessed for inclusion in the study by NRS-2002 rescreening conducted ≥ 1 week after admission to hospital.
[c] Value expressed as median (interquartile range).
[d] Patients with weight loss of ≥ 5% of body weight within the 3 months prior to screening by NRS-2002.
[e] Patients with respective dietary intake 0-25%, 25-50% and 50-75% of normal requirements for weight maintenance in the week prior to screening by NRS-2002.
[f] Patients discharged to another hospital or health care institution, which did not allow for follow-up interviews post-discharge.

Patients' hunger and fullness ratings directly before and after meals and the appetising effect of the meal are shown in Figure 1. The median (IQR) difference between VAS rating before and after meals was -21 (-43 - -11) percent for hunger and 34 (12 - 54) percent for fullness. Meals lasted a median (range) of 14 (4 - 35) minutes from the first to the last bite of food. Interviews related to snacks (n=2) were impromptu and as such, data on meal duration and hunger and fullness ratings were not included in the analysis. Amount of meal eaten was categorised in quartiles as < 500 kJ (n=14), 500 – 999 kJ (n=19), 1000 – 1500 kJ (n=15), or > 1500 kJ (n=5). Patients' VAS ratings for hunger and fullness before and after meals and the appetising effect of the meal, as shown in Figure 1, did not differ significantly for patients that consumed < 1000 kJ *vs.* ≥ 1000 kJ (results not shown). The 3-day food records completed post-discharge showed a median (IQR) daily intake of 5214 (4646 – 7277) kJ and 41 (35-59) g protein per day (n=12).

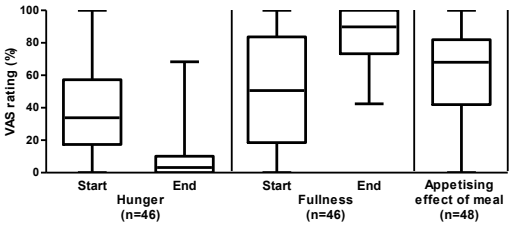

Figure 1 – Box-and-whisker plots of the patients' visual analog scale (VAS) ratings for hunger and fullness directly before and after meals and the appetising effect of the meal. VAS scores are reported as a value within a 100-mm scale.VAS ratings were not completed at n=7 meals as per the patient's request (n=2) or missing completion before and/or after the meal (n=5).

Meals varied in composition from a single beverage (e.g., a nutritional supplement) or a single food (e.g., soup) to multiple foods and drink. Some meal components were tasted and then otherwise left untouched if the sensory quality was deemed inappropriate (e.g., too strong tasting, too difficult to eat, generally unpleasant, etc.). Patients typically only took one serving of food. Specific illustrative meal observations are further described in relation to the results from the meal interviews as summarised in the following sections.

Semi-structured interviews

The following sections outline results from the semi-structured interviews. The first section is about the changed food sensory perception and eating ability experienced by patients at nutritional risk. The second section describes the patient's individualised food sensory needs (i.e., the appearance, aroma, taste, texture, temperature and variety defining food sensory quality that helped or hinder intake). The third and final section involves the patients' motivation to eat, including pleasure, comfort and survival, which provided an important context for patients' food sensory needs.

Food sensory perception and eating ability

Patients reported changed preferences to food sensory quality due to their illness and/or treatments, which changed proportionally to the severity of symptoms affecting food sensory perception and ability to eat (e.g., lack of appetite, early satiety, altered taste and smell perception, impaired swallowing and chewing ability, nausea and vomiting, dry mouth, gastrointestinal dysfunction and fatigue). One patient described her situation as *my appetite, my mouth, and my body are completely against each other... I couldn't taste because of a mouth infection and taste changes. I had some appetite, but I couldn't handle food in so large portions.* This patient and many others often struggled through trial and error to determine what and how much they should eat and drink. Some patients mentioned that they would have appreciated more guidance regarding appropriate menu choices for their specific situation.

Patients experienced problems with chronic or intermittent lack of appetite and/or early satiety to varying degrees. *I can't tell whether I'm hungry or full*, mentioned a patient and as explained by another: *Well, I think it's very hard because I have no real sense of it because I'm learning my limits with how much I need to eat.* Stringent meal patterns and routines were also often viewed necessary as described by a patient suffering from a lack of appetite: *It's not the cook. It's the clock that decides.* On the other hand, some patients would only eat when hungry despite advice from health care staff to eat small frequent meals; otherwise it felt unnatural and unpleasant for them: *Well, I should*

ideally eat every couple of hours and it's difficult to follow because it felt like I was eating all the time.

There was large inter- and intra-individual variation in patients' reactions to changed food sensory perception and eating ability. If food sensory quality was suboptimal, some patients stated that they were more likely to push a meal aside when ill as compared to when healthy. In a patient's words, *it wouldn't be worth popping in my mouth and risking throwing-up, for something that doesn't speak to me.* In contrast, other patients were surprised of the conditions under which they were still capable to eat: *I've previously thrown up my supper, but could very well eat afterwards because I didn't lose my appetite to what I was eating. So I can throw up, get it over with, drink some water and continue eating afterwards. It surprised me a bit that I could do that.* Another patient that had been battling cancer for a few years explained how her food preferences had changed so much that she could not remember what she liked anymore. She related this to having difficulty recognising her favourite foods when faced with a menu and therefore, appreciated meal suggestions.

Patients often set high demands to food sensory quality in order for them to eat, but this did not necessarily translate to dissatisfaction with their food. A number of patients felt that nothing was wrong with the food being served, but instead that they were abnormal: *I can see the others eat it and very well, but it's only me that is troublesome... I can't say anything positive or negative [about the food]. It depends on how I'm doing.* This highlights that patients were typically not conscious of their altered demands to food sensory quality to promote intake in relation to their symptoms.

Food sensory needs

When asked about the appearance, aroma, taste, texture, temperature and variety of food, patients were able to describe specific food sensory qualities that helped or hindered their food intake (i.e., food sensory needs).

Appearance: Patients stated that meal appearance was important for generating or maintaining their appetite. According to a patient suffering from nausea: *One can say that my problem sits up here (points to head) and I feel hunger down here (points to stomach) and it's up here (points to head) I should be tempted and that only happens when I look at food.* Meal appearance also gave an initial, overall impression of perceived quality: *[the food] should appear such that I think it will be a pleasant experience so that I can thereby become full.*

Appetising meals were often described as being small portions carefully arranged on the plate, whereas meals that were haphazardly arranged and/or spread all over the plate were highly criticised. For example, lunch meals, which typically comprised of open-faced sandwiches, were sometimes served helter-skelter on the plate and patients were expected to assemble their own sandwich. A few patients were critical of this. *It should look good on the plate and to be honest, when I get a piece of rye bread and a slice of luncheon meat on the side, it's darn boring to look at,* explained one patient. On the other hand, a patient from the infectious medicine department, where the nurses assembled the sandwiches served for lunch, had a completely opposite experience: *It was appealing plus it shows that those making the food go above and beyond and like to make food as opposed to just slapping some luncheon meat on... and even though I don't eat the vegetables, it looks nice… I think it also shows how much people care about when they cook and they like to cook.* This quote is also typical in that it describes the meal appearance in the context of the degree of caring and consideration by the individual preparing and plating the meal.

Preferred complexity of meal appearance varied between patients in which some preferred elaborate and garnished meals, whereas others preferred meals that appeared plain and simple with few ingredients. When starting to eat again after a period on enteral nutrition, a cancer patient stated: *Normally, I would think that it was sort of colourless, but that doesn't affect me because colourless equals peaceful at the moment. So that's fine by me.* Overly complex meals were deemed to be provocative and inappropriate during times of illness due to doubts as to whether one's body could handle such foods. Familiar foods were often preferred, but in some cases, led to great disappointment if the food did not meet the patient's expectations due to their changed sensory perception and/or eating ability.

Aroma: Some patients with low appetite found that the aroma of particular foods promoted their desire to eat (e.g., fresh bread, toast, sausages, soup, pancakes, rice). On the other hand, certain and/or general food smells were deemed revolting by other patients particularly those with nausea. A cancer patient suffering from anticipatory nausea and vomiting explained that: *I become nauseated just from the smell and I can't even go out by [the food wagon] because I always feel sick. That's why I get food from the outside.* Cold foods with limited smell (e.g., sushi, sandwich) were preferred by this patient. Another infectious medicine patient explained that: *aroma is often stronger with warm dishes such that one can become completely full from the aroma – well, it becomes sort of – whew too much.* Commercial nutritional supplements were disliked by some for their chemical smell and patients preferred flavours that masked this smell. The smell of a citrus flavoured supplement was described as being *similar to toilet water with a scent of toilet bowl cleaner.* Another patient preferred the strawberry, forest berry and orange flavoured supplements *because protein drinks have a special smell and [these flavours] mask that smell such that it seems more natural.*

Taste: Most patients preferred more natural flavours, such as being able to taste the tomato in tomato soup, real meat in sausages, real fruit in the fruit porridge, etc. One patient described this as *back to basics… in which I can taste that it is a tomato without all too much else because all the other things, I think it disturbs [the taste].* Also, for patients experiencing chemosensory changes, it was rewarding when foods actually tasted as expected from the raw ingredients. As such, patients were often critical of artificial flavouring.

Patients avoided spicy foods that were viewed to give stomach upset and/or heart burn. However, patients accustomed to spicier foods preferred them. Some patients preferred mild or neutral flavours since other flavours seldom lived up to expectations or were downright unpleasant due to severe chemosensory changes. For example, a cancer patient suffering from hypogeusia said: *I preferred yoghurt with nothing in it because I couldn't enjoy the taste anyways and I could just as well take yoghurt without taste.* This patient also noted having to be careful experimenting with really strong tasting food and drink since she was still sensitive to astringent and sharp flavours giving corresponding feelings of extreme warmth / coolness and irritation.

Patients often had difficulty discussing foods in relation to specific tastes (i.e., sour, salty, sweet, bitter, and umami). However, some patients described cravings for specific tastes, such as the following patient: *Well it changes a lot. All of a sudden, I crave something sour, just a split second… I remember dreaming a lot about a cold cola. But when I finally got one, I couldn't drink it or keep it down.* Sour tastes were desired by some patients often in relation to being refreshing and thirst-quenching (e.g., cold buttermilk dessert, certain fruits, pickled vegetables, cola, yoghurt, citrus flavoured drinks or desserts). Some patients emphasised the importance of having a sour side dish in order to promote consumption: *I like open-faced sandwiches, but preferably served with some pickled cucumbers or beets. There has to be something a bit sour so that I can eat more… it helps the appetite.* On the other hand, sharp, sour tastes were very unpleasant for patients suffering from oral sores or infections. Bitter tastes were also not preferred. Although the term umami was unfamiliar, some patients desired foods with stronger umami flavours (e.g., bouillon, soups, tastier cheeses, sausage). Patients were more familiar with characteristic salty foods (e.g., chips, peanuts, crackers) or sweet foods (e.g., cakes, candies, desserts) and experienced periodic cravings or dislike for these foods. Not all patients experienced cravings for particular tastes and many patients preferred being stimulated by a variety of tastes.

A number of the patients interviewed described taste changes to varying degrees. Some patients developed aversions to specific foods (e.g., coffee, tea, dark chocolate, wine, red meat) due to heightened bitter flavours or metallic tastes. Taste changes and aversions were a confusing and distressing situation for patients especially when previous favourite foods were suddenly avoided completely as stated by a patient: *It's weird because I've always liked chocolate a lot, but I don't care for it anymore. It's a strange development.*

Texture: When meals were an unpleasant or painful process, patients wanted to get over and done with

eating as quickly as possible. Therefore, foods that were *easy to eat and get down* were often chosen and soft and fluid foods were favoured. A patient commenting on his soup and a sausage lunch said: *It was a pleasant, fine consistency - much easier. I need something that is manageable, something I can see the end of. Not like a huge steak there, no thanks.* Patients suffering from dry mouth appreciated meals being served with an excess of sauce, dressing or anything to give moisture and serve as a lubricant. Certain dry foods (e.g. bread) were described by some patients as *expanding in their mouth*, which hindered eating. Also, some patients commented that foods, especially dairy products, left a sickly film in their mouth, which was rather unappetising. As described by a patient: *I normally like [lemon mousse] consistency, but I don't have any desire to eat it… It's soft, where you're chewing into nothing and of course it's tasty, but it wouldn't be good… It sits in the mouth just like if you eat bread that's a bit to moist and it sticks to the roof of the mouth and you can't get rid of it*. Patients were also generally critical of food textures that made meal situations more strenuous (e.g., foods that were difficult to cut and bones that had to be removed from fish or meat) and of troublesome packaging.

In contrast to favouring easy-to-eat foods, some patients were observed choosing open-faced sandwiches, which were more difficult to eat, as opposed to soup for lunch. This was attributed to wanting to get back to their usual food routines and since solid foods were viewed by some as better or healthier. Most patients preferred eating a variety of textures and consistencies, if they could manage, and patients that predominantly ate soft or fluid diet often missed the feel of biting into food and the contrast of crispy and crunchy textures.

Temperature: Many patients ate and drank slowly due to fatigue, impaired eating ability, functional impairments and distractions. As described by a patient: *I'm a slow eater, as you can see. I've noticed when eating with others that they can eat two to three times as much as I can in the same time. But, when they're finished, I'm also done.* As a result of slow eating, the serving temperature of meals often became compromised resulting in diminished quality and desire to continue eating the meal. There was however a patient that found meal situations particularly strenuous and typically spent up to two hours to complete her meals including several short breaks along the way. Although this patient was determined to eat her meals, she appreciated hot meals and experienced that they did not taste as well when they got cold. On the other hand, some foods and especially drinks (e.g., nutritional supplements) were considered more palatable when served ice cold. However, many patients had these drinks sitting for extended periods at the bedside tables allowing them to warm up and thus become less appetising over time.

Variety: Variety was considered important, but the nature and extent of the need for a variety of food and beverage choices differed between patients. Those that had more difficulty eating often required a variety of choices in order to find what they could manage to eat and drink and then stuck to that. As a result, they tended to eat similar foods and a more fixed diet, as explained by a patient: *Well, I've hardly had anything else. I try not to vary so much. I try to find foods that I know that my stomach can handle. I'm eating mostly fish because it feels as though my stomach likes it... Now, I'm eating what I know I can tolerate.* In contrast, other patients appreciated a variety of choices so that they did not get bored of eating the same things from day to day, as commented on by a patient: *I think already within a day and a half, the meals-on-wheels become rather boring with brown gravy and potatoes. On the other hand, I can get it down, but it's also pretty boring.* Furthermore, some patients got quickly bored of eating a particular dish, but could perhaps be tempted to start eating something different. These patients appreciated meal components with varied sensory properties. For example, some "Super diet" meals (e.g., brunch, tapas, cheese plate) were comprised of a variety of small attractive dishes and components that seemed appetising for some, as mentioned by a patient commenting on the brunch: *Perhaps five or ten little different toppings for instance. One is perhaps more interested in eating as such because they're different.* Most patients appreciated the choices offered by a buffet style foodservice: *I think it's great that you get to decide what you'll have and how much,* according to a patient. However, too much choice could be detrimental since some patients found overabundant and complex menus to be overwhelming.

Motivation to eat

During the study, motivation to eat emerged as a theme which provided an important context for understanding patients food sensory needs. Patients would refer to the nature and degree of their motivation to eat, or lack thereof, when describing their meals. They often reported how their motivation to eat changed during the course of their illness and treatment, from day to day, during the course of a day, and even during a single meal. From these results, three key motivational factors could be identified, which are categorised as: pleasure, comfort and survival. Often these motivational factors worked in combination and to varying degrees in a single meal.

Pleasure: The patient's enjoyment of food before becoming ill combined with their current ability to enjoy meals determined whether pleasure was a motivating factor to eat. There were a number of patients that enjoyed their meals to some extent and for which pleasure was a motivating factor to eat as stated by a patient: *When I eat something I like, then my appetite also comes.*

Some patients were indifferent about what they ate prior to their illness (e.g., *I'm normally not one who's like wow this tastes delicious*), whereas others had previously viewed meals as pleasurable and interesting. It was the latter group of patients that viewed unpleasant meal situations as particularly distressing, which resulted in diminished intake, as expressed by one such patient: *Nothing was appetising. It was a punishment for me to sit and eat at home… It was actually first when I was [admitted to hospital] last* Friday *that it started to improve… I got tube feeding overnight and I think it gave a good base so that I felt full and my eating improved on Friday…. [Before,] it was torture for me to eat and that'll never work.* A patient suffering from a multitude of eating-related symptoms became annoyed when asked about his meals in terms of liking: *I like? I like? It's not that I'm picky – it's just a challenge to have it in my mouth and to stomach it.* There was also an incident in which this patient was visibly frustrated by the food server attending the buffet who insisted on brightening up his plate with garnishing.

Comfort: Foods that helped eating-related symptoms and promoted physiological comfort were sought after, whereas foods that exacerbated symptoms were strictly avoided. For example, patients were motivated to eat foods that were stomach settling, pleasantly satiating, thirst quenching, refreshing, or that masked unpleasant tastes in the mouth.

Patients suffering from nausea and vomiting typically chose foods that they perceived as stomach settling (e.g., yogurt, rice pudding, crackers, ginger, and mints). A patient that ate *soft and neutral* foods when nauseated stated: *It's mostly, when I have an empty stomach that I become nauseated… It's just important to eat something, but that it's neutral.* When suffering from gastrointestinal discomfort, patients often selected foods that they found to be pleasantly satiating (e.g., porridge, soup, yogurt, fruit and vegetables). As explained by a patient: *The comfort and enjoyment of eating now is based on its satiating effect.*

Food and drink perceived as refreshing or thirst quenching (e.g., fresh fruit, ice lolly, and cola) were generally favoured, which was also heightened by the interviews being conducted in the summer. For example, one patient enjoyed eating a particular ice lolly, a vanilla ice cream coated with citrus flavoured sherbet, because it was *a little tart, a bit fresh and also cold*, whereas she did not care as much for others types of ice cream. Also, both cold and warm drinks and food were viewed as having comforting effects: *It's good with something cold to stimulate the throat,* stated one patient, whereas another said: *It's nice warm. I could feel it entering the stomach and then all the way through - that warmth. I like the warmth.*

Food and drink that masked unpleasant flavours or after-tastes, such as due to medications, were also chosen. A patient was observed drinking a quick glass of apple juice directly after having a nutrition supplement and when asked about this he stated: *It's to rinse it down… I like apple. It has a fresh taste.* Another patient chose foods based on aftertaste following vomiting: *I have a lot of nausea so I wonder how it tastes when it comes up again. It should preferably not be strong, acidic or sharp tasting. It's really horrible worrying about how the taste is.*

Patients also described being motivated to get back to their usual eating routines and found psychological comfort in eating familiar foods. For example, an Indonesian patient that happily ate ethnic dishes brought from home stated: *I'm so glad that they came with this food and so it helps give me energy. In any case, it's the best meal.* Another patient telling why she chose a particular dessert explained: *I took it because it's an old-fashioned dish that I know from my childhood, but very rarely get.*

Survival: Most of the patients regarded adequate food intake as an important part of their treatment and necessary for overcoming their illness. As exemplified by a patient: *Although I've been loathing food this last week, I've eaten anyways because I know that I'll get worse if I don't eat.* Some patients' dietary choices were clearly motivated by professional nutritional recommendations as stated by a patient: *Normally I don't drink whole milk, but I was informed that I should have it because I lack proteins.* Another patient explained his choice of a nutritional supplement in the morning, although he normally did not eat breakfast: *I can see the sense in having something so that I get some proteins in the morning, right?*

A patient that forced himself to eat said: *I would say that it's fuel. You need something to get well, right? But, it tasted hellish – it was no fun. The food wasn't enjoyable at all. So it was only because I should have it that I forced myself to eat it.* However, not all patients that forced themselves to eat disliked eating as per a patient's comments: *Although I didn't feel very hungry, I force myself to eat it and it tasted excellent.* In contrast, another patient experiencing severe eating-related symptoms and compromised functional status made particularly harsh comments about eating to survive: *I eat because I want to survive this. I know if I don't get anything to eat then it's my own grave that I'm digging. So I need to get something down and I also do and I'm willing when I'm here. But desiring and looking forward to having lunch soon, I'm completely indifferent about that.* Patients that viewed survival as their sole motivation to eat were often highly motivated, but did not always succeed to eat adequately and in some cases, relied upon periodic artificial nutrition.

Furthermore, some patients motivated by survival exhibited gross misunderstandings of dietary recommendations, some of which they heard through unreliable sources, and that motivated them to adopt inappropriate dietary practices. Also, patients that declined to participate in the study often did not view food in the context of survival. One such patient explained that he wanted to focus on his treatment in which food and nutrition was not considered an important component. Another patient viewed that it was expected that patients eat insufficiently and lose weight during hospitalisation, which he did not view to be problematic.

Discussion

Patients experiencing abnormalities in their sensory perception and eating ability displayed individualised needs of food sensory quality to promote intake. This corresponded to changes in motivation to eat including: pleasure, comfort and survival, which were often not apparent to the patients themselves. A model based on these observations is shown in Figure 2. The first category in the model, pleasure, was a motivating factor for patients, typically with mild symptoms, in which food could be somewhat enjoyed as when they were healthy. Appropriate foods in this context awakened appetite through appearance, aromatic smells, tastefulness and greater variety and complexity of the sensory properties. The second category, comfort, motivated patients to eat foods that promoted physiological and/or psychological well-being. Lastly, the third category, survival, included patients motivated by the importance of food for recovery from their illness and that, in some cases, had given up on enjoying food due to severe symptoms. Foods to promote intake in this context were plain and simple and had a texture and consistency that facilitated eating since the ultimate goal was to meet nutritional requirements and not to experience the food.

The model generated by this study provides a framework to develop food and drinks with qualities that address the food sensory needs of patients at nutritional risk segmented by their motivation to eat. Suggestions for food product development to promote intake based on the study's model are shown in Table 2. These foods and drinks then need to be tested to actually demonstrate an increase in food intake in nutritional risk patients.

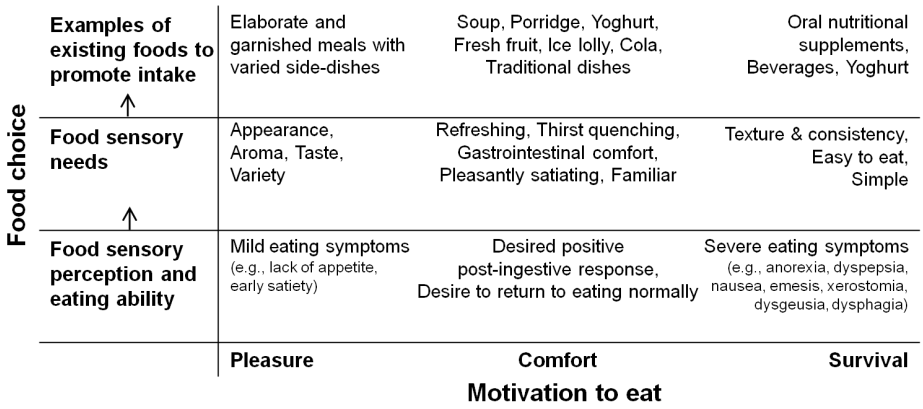

Figure 2 – Model of food sensory quality to promote intake in patients at nutrition risk. The process of choosing foods (y-axis) within the context of motivation to eat (x-axis) is shown. Food sensory perception and eating ability profiles correspond to specific food sensory needs (i.e., appearance, aroma, taste, texture, temperature and variety of the food), which coincides with examples of existing foods with sensory qualities to promote intake.

Table 2 – Suggested foods and drinks to be developed and tested, based on the model of food sensory quality.

Motivation to eat	Typical observations of food sensory perception and eating ability	Food product development suggestions
Pleasure	Patients quickly lost interest in eating or drinking a single food, but could perhaps be tempted to eat something else.	Develop meals comprised of multiple components and/or courses with varied sensory properties to minimise potential early sensory-specific satiety.
Comfort 1	Pleasant post-ingestive response following intake of particular food and drinks was described as a strong motivating factor for consumption.	Develop food and drinks that are associated with a positive post-ingestive response such as being stomach-settling, pleasantly satiating, thirst quenching and refreshing and masking unpleasant tastes in the mouth.
Comfort 2	Familiar food and drinks were often chosen, but led to disappointment when they did not live up to expectations of the sensory qualities as related to abnormal sensory perception and eating ability.	Develop familiar food and drinks that are adjusted to compensate for abnormal sensory perception and eating ability, e.g., increase moistness of foods for patients with dry mouth.
Survival	Patients wanted to get over with eating as efficiently as possible because they did not enjoy their food and often had great difficulties in eating.	Develop food and drinks with optimal texture and consistency that facilitates ease of eating (i.e., easy to form a bolus and swallow).

Observations of the present study support findings of earlier qualitative studies in patients at nutritional risk, e.g. enjoyment from meals being replaced by self-forced feeding,[16,18] eating by trial and error,[14,15] individual variation in eating being related to symptoms,[14] and trying to maintain previous eating patterns.[16] A model of factors influencing food experiences (i.e., well being, comfort, sorrow, and burden) was generated from a study in heart failure patients, being somewhat similar to the current model's motivating factors to eat.[17] The central aspect of motivation was also present in a study of Holst et al,[18] which characterised severely undernourished patients as being 'active' or 'passive' in their nutritional care. However, these studies[13-18] focused mainly on describing problems and less on strategies to improve food sensory quality to promote intake.

The present study is the first, to our knowledge, to investigate this topic applying different methods (e.g., meal observations, VAS ratings, food records and interviews) in a prospective, longitudinal design during hospitalisation and post-discharge, thereby producing an operational framework that can be subjected to clinical testing (Figure 2, Table 2). Change in hunger and fullness ratings during the meal was not significantly different for patients when grouped according to their calorie intake, suggesting the importance of early satiety for stopping a meal.

Limitations of the study should also be taken in consideration. Food choices by patients during meal observations might have been influenced by the presence of the investigator. Patients seemed generally positive and at ease in the investigators presence, which might have encouraged food intake. The study did not include views from patients that declined to participate in the study and who were generally more apathetic regarding the study topic. Furthermore, the study population was culturally homogenous including mostly ethnic Danes and some of the results might not be generalisable internationally due to the influence of food culture. Other meal-related issues, such as social aspects, serving environment, eating pattern, support from care providers, and access to appropriate food choices were discussed if mentioned by the patient. However, these results are not presented in accordance with the study's aim to investigate food sensory quality and not to negate the potential importance of these other factors on food intake.

Based on the results of this qualitative study, a quantitative questionnaire about patients' eating-related symptoms, food sensory preferences, and motivation to eat has been developed. This questionnaire has been used to examine the prevalence of the findings of this study in a larger group of patients.[25] The model generated by these studies can be used to develop user-driven, innovative food and drinks to promote intake in patients at nutritional risk.

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Appendix 5: Paper II

Food sensory needs of patients at nutritional risk: a questionnaire study

Food sensory needs of patients at nutritional risk: a questionnaire study

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Short title: Food sensory needs of patients at nutritional risk

Non-standard abbreviations:

- BMI, body mass index
- IQR, interquartile range
- LOS Quest, length of stay on the day of the questionnaire
- NRS-2002, Nutritional Risk Screening-2002
- PC, principal component
- PCA, principal component analysis

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Abstract

Background & Aims: The study aimed to investigate food sensory quality as perceived by a diverse group of patients at nutritional risk in order to guide food development to improve intake.

Methods: Hospital patients at nutritional risk (NRS-2002) completed a questionnaire about their eating-related symptoms (15 three-point scale questions) and food sensory needs and motivation to eat (46 Likert scale questions) developed based on a qualitative study. Demographic and nutrition information was collected. Descriptive statistics and associations with energy and protein intake were assessed. Principal component analysis (PCA) assessed associations between variables.

Results: Questionnaires (N=200) were done in departments of infectious medicine, cardiology, gastrointestinal surgery, rheumatology, oncology, and haematology. Intake was positively associated with enjoying eating, preference for different tastes, sour side dishes, and sour, savoury, and pleasantly satiating foods and negatively associated with forced eating, low appetite, early satiety, stomach pain, nausea, taste changes, swallowing problems, nauseating aromas, difficulty forming a bolus, and preference for 'light foods', familiar foods, and foods tasting as preferred. PCA segmented patients by motivation to eat: pleasure *vs.* survival and contrasting food sensory needs: awakening appetite *vs.* facilitating intake.

Conclusions: Food products developed for segment groups, e.g., awakening appetite *vs.* facilitating intake, could perhaps promote food intake in patients at nutritional risk.

Keywords: disease-related malnutrition in hospital, food choice, food sensory quality, low appetite, early satiety, Principal Component Analysis.

Introduction

Hospital undernutrition, which leads to a higher risk of complications, longer lengths of hospital stay and additional costs for healthcare systems,[1,2] can be greatly attributed to inadequate food intake in patients despite adequate food provisions.[3,4] This leads to large amounts of plate waste[5] and worsening nutritional status during hospitalisation.[6] Initiatives to optimise hospital food quality and thereby promote adequate food intake are typically guided by patient foodservice questionnaires,[7,8] which assess patient satisfaction with the foodservice for which there is an assumed positive relationship to food intake. However, a prospective study in geriatric patients[9] found that food intake was not associated with patient satisfaction with the food, service or overall, but instead was associated with perceived food sensory quality (i.e., tastefulness, appropriateness of food temperature and texture, palatability).

We have recently suggested, based on a qualitative study,[10] that patients at nutritional risk have individualised food sensory needs. Patients in this study experienced changes in their sensory perception and eating ability and motivation to eat (e.g., pleasure, comfort, and/or survival), which related to food sensory properties to promote intake. Patients that found eating pleasurable typically had milder eating-related symptoms and preferred foods that awakened their appetite through varied food sensory properties. Patients motivated by comfort ate foods in order to improve their physiological and/or psychological comfort (e.g., foods perceived to be pleasantly satiating, refreshing, and familiar). Patients motivated by survival typically had more severe eating-related symptoms and chose simple foods that were easy to eat. A model of food choice in patients at nutrition risk, which related to food sensory needs within the context of motivation to eat, was developed from these results.

This study aimed at determining the prevalence of eating-related symptoms and factors related to food sensory needs and motivation to eat in a heterogeneous group of patients at nutritional risk using a questionnaire developed based on the qualitative study for this aim. Furthermore, the questionnaire variables were assessed as related to sufficiency of energy and protein intake to cover requirements and associations between the variables were assessed to investigate dimensions of food choice within the context motivation to eat (e.g., pleasure *vs.* survival). Both the current investigation and the previous qualitative study were conducted to provide information to help guide food product development and optimisation of food sensory quality to promote intake in patients at nutritional risk.

Materials and Methods

Questionnaire development and design

The patient food choice questionnaire consisted of 61 questions divided into two parts. The first part described sensory and eating ability in terms of 15 eating-related symptoms: low appetite, early satiety, nausea, vomiting, dry mouth, mouth pain or discomfort, throat pain or discomfort, stomach pain or discomfort, problems chewing, problems swallowing, diarrhea, constipation, need for assistance when eating, food allergy or intolerances, and taste changes. Patients were asked to state the degree to which they currently experienced each symptom on a three-point scale (i.e., 'not at all', 'somewhat', 'very much') and to specify the nature of eventual food allergy or intolerances and/or taste changes. The second part of the questionnaire dealt with food sensory needs and motivation to eat. It was comprised of 46 statements on nutritional risk patients' food sensory experiences and preferences divided into 6 sections: appearance (6 statements), aroma (2 statements), taste (12 statements), texture and consistency (10 statements), temperature (1 statement) and variation (6 statements) of meals as well as motivation to eat (7 statements) (Table 3). For each statement, patients were asked how much they agreed or disagreed with the statement on a five-point Likert scale (i.e., 'fully agree', partially agree', 'neither agree nor disagree', 'partially disagree', 'fully disagree'). Patients were instructed to answer the questionnaire based on their current condition, experiences, and preferences.

The order that questions were asked is shown in Table 2 and Table 3. The questionnaire was developed in Danish and translated into English for this publication.

The qualitative study[10] provided the basis for the content and wording of questions. This helped to optimise the relevance and comprehension of the questionnaire for patients at nutritional risk. Also, considering that many patients did not eat for pleasure, statements in the second part of the questionnaire on food sensory needs were formulated predominantly in relation to influence on intake, rather than influence on liking. The content and format of the questionnaire was discussed with and revised in conjunction with all authors, who provided different interdisciplinary perspectives from the areas of dietetics, sociology of food, food sensory science, gastronomy and clinical nutrition medicine. Additional advice on the questionnaire was provided by an interdisciplinary group of colleagues that worked with patients at nutritional risk including three clinical dietitians, a clinical nurse specialist and a foodservice employee. Finally, the questionnaire was pilot-tested in hospitalised patients (N=13), focusing on whether questions were interpreted correctly and consistently.

Participants

Questionnaires were administered in conjunction with four different studies as described below. These studies had different aims and some different inclusion criteria, but regardless, all questionnaires were completed at entry into the study when all other baseline data were collected. Therefore, the patients' meal experiences and preferences did not have the opportunity to be affected by procedures of the study at hand.

In the current study (*study 1*), patients were recruited from non-intensive care departments of gastrointestinal surgery, infectious medicine, cardiology, oncology, haematology and rheumatology at Copenhagen University Hospital (Rigshospitalet). All adult patients (≥ 18 years old) found to be at-risk according to nutritional risk screening (NRS-2002[11] ≥ 3) at admission to hospital or at weekly re-screening were assessed for participation in the study. Potential participants were also required to be eating normally (i.e., not relying on enteral or parenteral nutrition to meet their requirements). Patients were excluded if unable to communicate coherently, e.g., due to mental illness, cognitive impairment, or language barriers. Patients were also excluded if they did not provide informed consent as required by the study protocol, which was approved by the local Biomedical Ethics Committee for The Capital Region of Denmark. In addition to this, patients that completed the questionnaire in *study 2, 3,* and *4* also: had to be able to feed themselves sitting up and an expected length of stay in hospital of at least two or three days for *study 2* and *study 3*, respectively, or had an expected length of stay of at least five days and the ability to conduct handgrip strength for *study 4*.

Data collection

Questionnaires were completed by patients during hospitalisation with the assistance of the study investigator (JS) or trained research assistants involved in conducting the study. This was done to ensure standardised and complete entry of the questionnaire and to reduce respondent burden, especially for those that were fatigued or had physical or visual impairments that hindered their ability to complete the questionnaire on their own. Patients were briefly informed of the nature of and the number of reply categories for each of the two parts of the questionnaire. It was emphasised that patients were to reply to the questions in regards to how they were currently feeling. Questions were read aloud to the patients and repeated if requested.

Categories of the five-point Likert scale were offered in a stepwise manner so as not to overwhelm the patient (i.e., asking first: "Do you agree or disagree?" followed by: "Do you agree/disagree fully or partially?"). Additional comments and indications of confusion regarding questions were noted. It took about 15-30 minutes to complete the questionnaire, which varied considerably depending on the extent of additional comments from the patient. To reduce interviewer bias, all research assistants were trained first hand by the study investigator regarding these standardised techniques and instructed to follow a

common study protocol for administration of the questionnaire.

Baseline patient demographic characteristics collected at admission into the study included information on age, gender, department, diagnosis, immigrant status, educational level, nutritional risk status, and length of stay in hospital on the day of the questionnaire (LOS Quest). Total length of hospital stay and discharge destination was also recorded.

Nutritional risk status was determined by NRS-2002[11] in which the nutritional risk score is calculated by adding the 'Nutritional Score' of 0 to 3 to the 'Severity of Disease Score' of 0 to 3 plus a score of 1 for patients older than 70 years. The 'Nutritional Score' is defined by adequacy of dietary intake in the previous week assessed as quartiles of requirement, presence of ≥ 5% weight loss in a specified period within the last three months and body mass index (BMI). Body weight was obtained by weighing and height was obtained from the patients. The 'Severity of Disease Score' is meant to reflect increases in protein requirements caused by stress metabolism. It is defined by the condition of the patient: chronically ill, but ambulatory; confined to bed due to illness; or in intensive therapy. A total score of 3 or more indicates risk for undernutrition that should be treated.

Energy and protein intake was determined retrospectively by 24-hour recall for *study 1* and prospectively by dietary and activity records completed by the patient and/or nursing staff on the day of the questionnaire for *study 2, 3,* and *4*. Dietary recording was done by visual assessment in quartiles[12] as related to weighed reference portions for hospital menus and food items. Energy and protein content of foods was based on Danish nutritional data from the Master Cater System (Anova Data, Holte, Denmark). Energy requirements were calculated by the factorial method by Nielsen et al.[13] in liver cirrhosis patients and as modified from Acherson et al.[14] in which basal metabolic rate as per the Harris Benedict equation is multiplied by an activity factor and a stress factor. This method has also been evaluated in a heterogeneous group of patients.[15] The average daily activity factor was calculated from recordings of 'lying sleeping', 'lying awake', 'sitting', 'walking' and 'training' with corresponding activity factors of 0.9, 1.2, 1.3, 2.5 and 7, respectively.[16] Stress factors of 1.2, 1.3 and 1.4 were used for patients with fever of 38ºC, 39ºC and 40ºC, respectively.[17] An adjusted body weight based on the metric Hamwi method[18] was used for obese patients (BMI>30kg/m^2). Protein requirements were set at 18% of energy requirement.[19] Energy and protein balance was calculated in terms of percent of requirements met by the daily intake.

Statistical analysis

Descriptive statistics were presented as median (interquartile range (IQR)) for nonparametric continuous variables and as number (percentage) (N (%)) for categorical variables including the three-point and five-point Likert scales of the questionnaire. The Mann-Whitney U, Kruskal-Wallis H, and Jonckheere-Terpstra tests were used to compare differences between binary, multinomial, and ordinal variable categories, respectively. Department categories were treated as binary variable (i.e., 1 or 0; a single department *vs.* all remaining departments). Significant Kruskal-Wallis H tests were followed by post-hoc paired comparisons using Mann-Whitney U tests with Bonferroni adjustments. Correlation between continuous variables was assessed by Pearson or Spearman rank correlation test for parametric or nonparametric comparisons. These analyses were conducted using SPSS (version 17.0, SPSS Inc, Chicago, USA) and statistical significance was set at $p < 0.05$.

Principal Component Analysis (PCA) was used to examine association between variables. PCA transforms a set of possibly associated observed variables into a smaller set of unassociated principle components (PC). The first principal component (PC1) accounts for the most variability in the dataset followed by the second principal component (PC2), which accounts for the second most variability in the data, and so on. PCA was used to identify patterns in the patient demographic, nutritional status and patient food choice questionnaire results. Data was auto-scaled prior to analysis (i.e. scaled to the unit of

variance) and, as appropriate, sparse missing values (i.e., ≤ 3% of patients) were extrapolated using the model (i.e., "replaced with best guess" in PLS-toolbox 5.0.3). The number of principal components retained in the model was determined using the scree-test, which helps to differentiate the meaningful principal components from those indicative of random error (i.e., plotting the descending eigenvalues against their principal component numbers and including those with the highest eigenvalues until a there is a break in the slope and a levelling off of the plot). The model was cross-validated using random subsets of the data. The score plot of Q residuals (i.e., a lack of model fit statistic) *vs.* Hotelling's T^2 was used to identify outliers (i.e., outside of the 95% confident limits). The Q-residual contributions plot of identified patients was consulted to determine potential variables responsible for deviation from the model. PCA score plots and loading plots provided graphical representation of the patients and variables, respectively, in relation to the principal components. The variance explained for individual variables in the PCA model was calculated using the 'varcap' function. Patients were grouped according to their PCA scores (i.e., positive *vs.* negative) and were compared using Mann-Whitney U test. The positive and negative PCA scores were denoted by PC (+) and PC (-), respectively. PCA was conducted using PLS toolbox (version 5.0.3 (Eigenvector Research Inc., Wenatchee, USA) for MATLAB (version 7.10.0 (R2010a), The MathWorks, Natick, USA).

Results

Hospitalised patient population

A total of 66 patients completed the questionnaire in conjunction with the *study 1*, all of which were included in the analysis. The three subsequent, *study 2*, *3*, and *4*, included 150 patients of whom 135 (90%) agreed to complete the questionnaire and only one of these patients was excluded from the analysis due to excessive missing data. Collectively, a total of 200 patients were included in the analysis from the *study 1* (n=66), *study 2* (n=29), *study 3* (n=29) and *study 4* (n=76) studies.

Demographic characteristics and nutritional status of the patients included in the analysis are shown in Table 1. Data presented in this table are complete apart from activity factor and energy and protein intake and balance for six patients, which resulted in N=194 for these variables. This data was unavailable because of missing (n=1) or incomplete dietary and activity records due to early discharge (n=2) and drop-out from the study (n=3) on the day of the questionnaire. The patients' energy balance was significantly higher than their protein balance ($p < 0.001$).

Patient food choice questionnaire

The patients' eating-related symptoms, as reported in the first part of the questionnaire, are shown in Table 2. Low appetite, early satiety, dry mouth, and taste changes were the most common eating-related symptoms. The least common symptoms reported included food allergies and intolerances, and problems chewing. Also, only a few patients expressed a need for assistance when eating, which according to patients' comments, related to various issues from diminished hand function to depression.

Patients were asked to describe the nature of their food allergies and intolerances and/or taste changes. Reported food allergies and intolerances could be categorised as perceived intolerances (53%), allergies (35%), and medical dietary restrictions (12%). The 115 patients with taste changes described their symptoms as: distorted taste (33%), weaker/absent taste (24%), stronger taste (15%) or no description was given (28%). Patients with distorted taste had mostly problems with a taste of metal/iron or medicine/bitter. Some patients described their symptoms as resulting in a decreased desire for some or all foods, whereas other patients seemed less affected. Problematic food and drinks mentioned were quite variable including: coffee, soup, bread, sweets, strawberries, fish, chocolate, meat, red wine, nutrition drinks and water. Some patients stated the cause of their taste changes, which they believed to be attributed to: chemotherapy, medicine, smoking cessation, or oral thrush.

The results of the second part of the questionnaire on food sensory experiences and preferences and

motivation to eat are given in Table 3. The top five statements that patients fully or partially agreed upon were (in abbreviated form; for complete phrases confer with Table 3): Q6: appetising appearance, Q10: taste of raw ingredients, Q5: small portions, Q20: preferred taste and Q30: refreshing/thirst quenching. The bottom five statements that the least number of patients fully or partially agreed upon were: Q38: difficulty tolerating foods, Q22: soft or fluid foods, Q14: salty foods, Q33: temperature problems, Q25: film left in mouth, Q15: sweet foods and Q18: mild/neutral flavours. The top five statements that most evenly split patients (i.e., smallest difference between agree *vs.* disagree) were: Q44: eating as per recommendations, Q17: variable taste changes, Q19: spicy foods decreasing desire to eat, Q21: easy to eat, and Q40: eating only when hungry. However, most patients took a stance of either agreeing or disagreeing with the statements since only 1-14% of patient 'neither agreed nor disagreed' with the statements.

Questionnaires were fully completed apart from only two answers missing about taste changes due to interviewer oversight. Notes on lack of understanding of the patient food choice questionnaire were only recorded for patients in *study 1* since only a few patients required explanation for some of the statements in the second part of the questionnaire. The five statements that required most frequent explanation, in descending order, included: Q10: taste of raw ingredients, Q13: savoury foods, Q9: dislike of artificial flavours, Q31: pleasantly satiating and Q37: difficulty knowing what to eat. These questions were each clarified for 3 to 5 (5-8%) of the 66 patients in the *study 1*. As based on comments during the questionnaire, patients often needed to be reminded to reply as per their current condition. This was particularly challenging for patients that had experienced highly variable eating-related symptoms. Furthermore, some patients were prone to focus on the specific food examples used in some questions (e.g., Q11 to Q15) as opposed to the general sensory properties being discussed. However, results from the pilot-testing found that example foods were advantageous to promote comprehension of some statements and to be more helpful than omitting them.

Univariate analysis of variables as related to energy and protein balance

The patients' demographic characteristics, nutritional status, and patient food choice questionnaire results were further assessed in relation to their energy and/or protein balance:

Energy balance was *positively* associated with or significantly *higher* in relation to the following continuous or categorical variables, respectively: Q41: enjoy food ($p < 0.001$); age, cardiology, Q13: savoury foods, and Q16: different tastes ($p < 0.01$); and Q12: sour side dishes ($p < 0.05$).

Protein balance was *positively* associated with or significantly *higher* in relation to the following continuous or categorical variables, respectively: age, Q41: enjoy food ($p < 0.001$); cardiology ($p < 0.01$); and Q11: sour foods, Q16: different tastes, Q13: savoury foods and Q31: pleasantly satiating foods ($p < 0.05$), i.e., the same as for energy balance apart from: Q12, Q11, and Q31.

Energy balance was *negatively* associated with or significantly *lower* in relation to the following continuous or categorical variables, respectively: NRS-2002 intake score, and low appetite ($p < 0.001$); oncology, stomach pain, Q8: nauseating aromas, and Q26: 'light foods' ($p < 0.01$); and BMI, early satiety, nausea, taste changes, Q1: familiar foods, Q20: preferred taste, and Q24: difficulty forming bolus ($p < 0.05$).

Protein balance was *negatively* associated with or significantly *lower* in relation to the following continuous or categorical variables, respectively: NRS-2002 intake score, and low appetite ($p < 0.001$); oncology, nausea, stomach pain, Q8: nauseating aromas, and Q24: difficulty forming bolus ($p < 0.01$); and gastrointestinal surgery, early satiety, problem swallowing, Q1: familiar foods, Q20: preferred taste, Q26: 'light foods', and Q45: forced eating ($p < 0.05$); i.e., the same as for energy balance apart from: BMI, taste changes, gastrointestinal surgery, problem swallowing, and Q45.

No significant relationships to energy or protein balance were found for other variables.

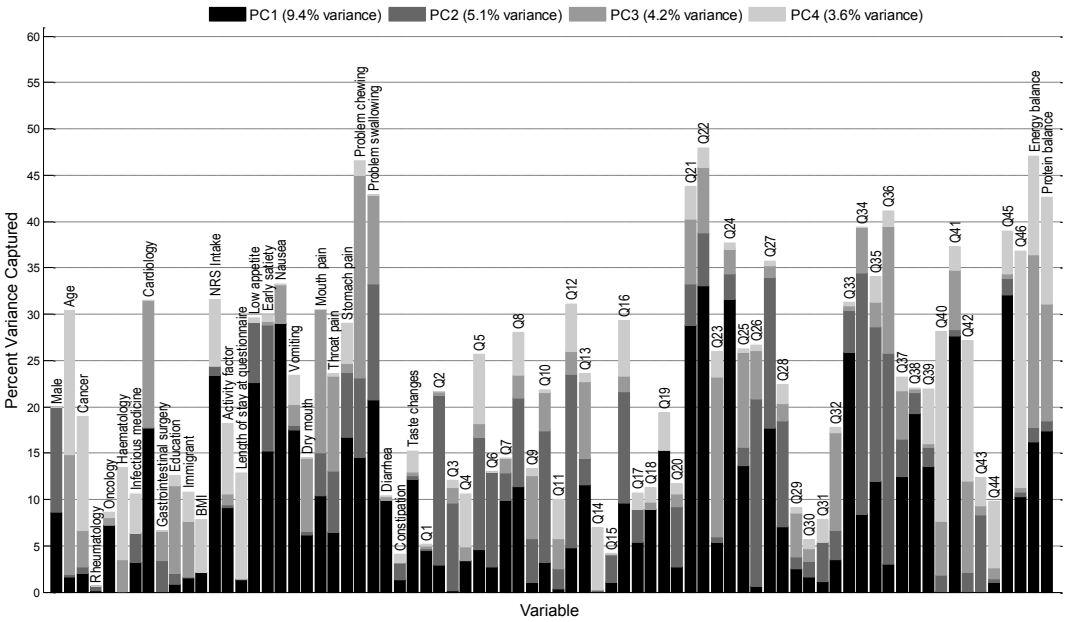

Fig 1 – Percent variance captured by a four principal component model of the data. The variance explained for the individual demographic, nutritional status and food sensory questionnaire variables are represented by the bars. The different coloured sections of the bars from darker to lighter represent PC1 to PC4 included in the model and as explained at the top of the figure. Q1 to Q46 are described in more detail in Table 3. (N=200)

Principal component analysis (PCA)

A total of 76 demographic, nutritional status and patient food choice questionnaire variables were included in the final PCA model (Fig 1). Two additional eating-related symptom variables, 'Need for help eating' and 'Food allergies and intolerance', were removed from the final model based on their high Q residual contributions (data not shown) and low prevalence. The final PCA model was comprised of four principal components, which cumulatively explained 22.3% of the variance in the data. The first principal component (PC1) explained 9.4% of the variance, the second (PC2) 5.1%, the third (PC3) 4.2%, and the fourth (PC4) 3.6%. For clarity, only PC1 and PC2 will be dealt with in detail in the following. The PCA model explained from 0.7% to 47.9% of the variance of individual variables as shown in Fig 1. Among the variables with the most variance explained were energy balance and protein balance.

The loading plot of variables for *PC1 vs. PC2* is given in Fig 2. Principal components were interpreted by dividing patients into groups based on their positive or negative scores for the two principal components. The groups were named based on the authors' interpretation of the results. Significant demographic characteristics, nutritional status variables, and food choice questionnaire replies that varied between groups when comparing PC (+) vs. PC (-) for PC1 and PC2 are shown in Table 4.

PC1 segmented patients into *'forced eating'* (PC1 (+)) and *'enjoy eating'* (PC1 (-)) groups as interpreted by the authors. This was characterised by Q45: forced eating on the positive side and Q41: enjoy food on the negative side of the PC1-axis. PC1 (+) was associated with many eating-related symptoms and problematic food sensory experiences (Q8, Q24, Q25, Q33, Q35, Q37, and Q38). Patients with positive PC1 scores were also associated with a preference for milder flavours (Q18 and Q19), foods that were easy to eat (Q21), familiar foods (Q1), and eating soft or fluid foods (Q22). A view of food as important for recovery (Q46) and forced eating (Q45) was also associated with PC1 (+) patients. Despite this, PC1 (+) patients had lower dietary intake based on a positive association with NRS intake score (i.e., lower intake in the last week) and an inverse association to energy and protein balance.

Table 1 – Patient demographics and nutritional status (N=200).

		N (%) or median (IQR) [a]
Age, years		60 (47 – 68)
Male		109 (55%)
Department		
	Infectious medicine	57 (29%)
	Cardiology	44 (22%)
	Gastrointestinal surgery	33 (17%)
	Rheumatology	24 (12%)
	Oncology	24 (12%)
	Haematology	18 (9%)
Immigrant		21 (11%)
Education		
	Lower than secondary education	50 (25%)
	Secondary education	11 (6%)
	Trade school	65 (33%)
	Short higher education	16 (8%)
	Medium higher education	40 (20%)
	Long higher education	18 (9%)
Primary diagnosis [b]		
	Infection, incl. pneumonia	60 (30%)
	Heart disease, incl. other cardiovascular	29 (15%)
	Solid tumor	26 (13%)
	Other medical disease	24 (12%)
	Haematology	17 (9%)
	Observation	16 (8%)
	Minor abd. surgery, incl. appendicitis	16 (8%)
	Major abdominal surgery	12 (6%)
Cancer		66 (33%)
NRS-2002		
	Rescreening [c]	65 (33%)
	Body mass index, kg/m^2	22.1 (19.6 – 25.9)
	Weight loss ≥ 5% [d]	138 (69%)
	Intake 0-25% [e]	37 (19%)
	Intake 25-50% [e]	91 (46%)
	Intake 50-75% [e]	55 (28%)
Energy intake, kJ/day [f]		6588 (5130 – 8855)
Protein intake, g /day [f]		57 (40 – 83)
Activity factor [f]		1.14 (1.10 – 1.18)
Energy balance, % [f]		99 (73 – 131)
Protein balance, % [f]		83 (57 – 112)
Length of stay at questionnaire, days [g]		6 (3 – 11)

[a] Categorical variables expressed as N(%) and continuous variables expressed as median (IQR).

[b] Diagnoses were entered from a list of diagnosis categories based on Sorensen et al.[1]

[c] Patients assessed for inclusion in the study by NRS-2002 rescreening conducted ≥ 1 week after admission to hospital.

[d] Patients with weight loss of ≥ 5% of body weight within the 3 months prior to screening by NRS-2002.

[e] Patients with respective dietary intake 0-25%, 25-50% and 50-75% of normal requirements for weight maintenance in the week prior to screening by NRS-2002.

[f] Six patients were excluded from the analysis of activity factor and energy and protein intake / balance due to missing (n=1) or incomplete (n=5) dietary and activity records for the day of the questionnaire. (N=194)

[g] Length of stay in hospital at time of questionnaire completion.

Table 2 – Patient food choice questionnaire: eating related symptoms (N=200).[a]

Symptom	'Not at all'	'Somewhat'	'Very much'
Low appetite	30 (15%)	63 (32%)	107 (54%)
Early satiety	42 (21%)	56 (28%)	102 (51%)
Nausea	104 (52%)	73 (37%)	23 (12%)
Vomiting	146 (73%)	44 (22%)	10 (5%)
Dry mouth	67 (34%)	62 (31%)	71 (36%)
Mouth pain or discomfort	146 (73%)	34 (17%)	20 (10%)
Throat pain or discomfort	139 (70%)	36 (18%)	25 (13%)
Stomach pain or discomfort	118 (59%)	49 (25%)	33 (17%)
Problems chewing	169 (85%)	17 (9%)	14 (7%)
Problems swallowing	151 (76%)	29 (14.5%)	20 (10%)
Diarrhea	129 (65%)	45 (23%)	26 (13%)
Constipation	137 (69%)	41 (21%)	22 (11%)
Need for help eating	192 (96%)	6 (3%)	2 (1%)
Food allergies and intolerances	182 (91%)	17 (9%)	1 (1%)
Taste changes [b]	83 (42%)	65 (33%)	50 (25%)

Table 3 – Patient food choice questionnaire: food sensory experiences and preferences and motivation to eat (N=200).

Section	Questionnaire statement	Agree/Disagree [a]
Appearance	Q1 I prefer to eat food that is familiar.	72% A
	Q2 I prefer food that is garnished with greens or different colours.	66% A
	Q3 I prefer that dishes, e.g., meat, potatoes, sauce, etc., are not mixed together.	65% A
	Q4 I prefer simple food with little garnishing and made of few ingredients.	59% A
	Q5 I prefer small portions.	87% A
	Q6 It is important that my food appears appetising in order for me to eat it.	94% A
Aroma	Q7 The aroma of some foods, e.g., fresh bread, is appetising and promotes my desire to eat.	79% A
	Q8 The aroma of food can give me, e.g., nausea, and decrease my desire or ability to eat.	56% A
Taste	Q9 I do not care for artificial flavours, e.g., flavour of oral nutritional supplements.	72% A
	Q10 It is important to be able to taste the raw ingredients, e.g., tomato in tomato soup.	93% A
	Q11 I prefer sour foods, e.g., yoghurt, sour drinks, pickles, etc.	53% A
	Q12 When I eat a rich meal, it's important to eat something fresh/sour on the side, e.g., pickle.	69% A
	Q13 I prefer foods, e.g., cheese, sausages and bouillon, which are more flavourful.	74% A
	Q14 I prefer salty food, e.g., chips, peanuts, saltines, etc.	69% D
	Q15 I prefer sweet foods, e.g., cakes, pastries, candy, desserts, etc.	55% D
	Q16 I prefer foods with different tastes, e.g., sour, sweet, salt and so on.	77% A
	Q17 My desire for different tastes changes all the time.	50% D
	Q18 I prefer food with a mild / neutral flavour.	55% D
	Q19 Spicy flavours decrease my desire or ability to eat.	50% D
	Q20 It is important that my food tastes as I prefer in order for me to eat it.	86% A
Texture & Consistency	Q21 I prefer mostly food that is easy to eat, i.e., easy to chew and swallow.	54% A
	Q22 I eat only soft or fluid foods.	72% D
	Q23 I prefer food that is moist, served with lots of sauce or dressing.	58% A
	Q24 Sometimes food expands in my mouth, which decreases my desire or ability to eat.	58% A
	Q25 Sometimes foods, e.g., dairy products, leave a film in my mouth, decreasing my desire to eat.	57% D
	Q26 I prefer 'light foods', e.g., lots of vegetables, as opposed to fatty food.	61% A
	Q27 I like the feeling of crispy or crunchy foods, e.g., fresh vegetables, bacon, or crackers.	66% A
	Q28 I prefer foods with varying consistency, e.g., pot pie with crunchy pastry and soft filling.	80% A

Section	Questionnaire statement	Agree/Disagree [a]
	Q29 I feel that my body needs a more solid diet, e.g., sandwich as opposed to soup for lunch.	55% A
	Q30 I prefer food that is refreshing and thirst quenching, e.g., fresh fruit, popsicles, cola, etc.	82% A
	Q31 I prefer food that is pleasantly satiating, e.g., oat porridge, yoghurt, fruit, fish, etc.	75% A
	Q32 It is important that the consistency of my food is as I prefer in order for me to eat it.	80% A
Temperature	Q33 I eat slowly, which can compromise the food temperature and my desire to continue eating.	57% D
Variation	Q34 I prefer dishes that are varied in terms of taste, texture, consistency and temperature.	77% A
	Q35 I quickly lose the desire to eat, but I can perhaps be tempted to eat something else.	54% A
	Q36 I prefer to eat varied and different foods daily in order to increase my desire to eat.	71% A
	Q37 It is difficult to know what I would like to eat from meal to meal.	77% A
	Q38 I have difficulty finding food that my body can tolerate.	79% D
	Q39 I eat mostly the same things from day to day.	61% A
Motivation to eat	Q40 I eat only when I am hungry.	54% A
	Q41 I enjoy my food.	65% A
	Q42 It is important for me that I enjoy my food in order for me to eat it.	74% A
	Q43 I strive to eat foods, which I believe are healthy for my body.	60% A
	Q44 I choose food and drinks based on recommendations from my doctors, nurses and dietitians.	47% A
	Q45 I often force myself to eat.	60% A
	Q46 I eat to overcome my illness.	78% A

[a] Percent of patients that fully or partially agreed A) or fully or partially disagreed D) with each statement is shown based on the most prevalent response. Results for 'neither agree nor disagree' are not included in the table.

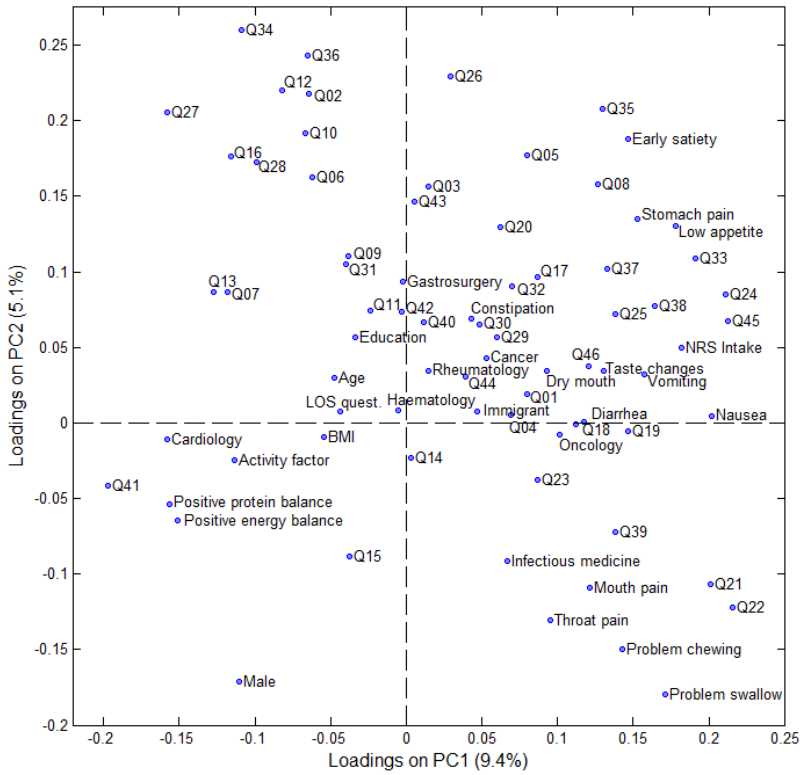

Fig 2 – Loading plot of PC1 vs. PC2 including the demographic, nutritional status and patient food choice questionnaire variables used in the PCA model. Variables with the highest absolute loading values (given in brackets) were for PC1 (+) vs. (-): Q22: soft/fluid (0.216), Q45: forced eating (0.212), Q24: difficulty forming bolus (0.211), nausea (0.202), and Q21: easy to eat (0.201) *vs.* Q41: enjoy food (-0.197), Q27: crispy/crunchy (-0.158), cardiology (-0.158), energy balance (-0.156), and protein balance (-0.151); and for PC2 (+) vs. (-): Q34: varied dishes (0.260), Q36: varied daily (0.243), Q26: 'light foods' (0.229), Q12: sour side-dishes (0.220), and Q2: garnished (0.218) *vs.* problems swallowing (-0.180), male (-0.171), problems chewing (-0.150), throat pain (-0.131), and Q22: soft/fluid (-0.122). (N=200) Refer to Table 2 and 3 for further explanation of the questionnaire variables.

Table 4 – Patient characteristics by PC1 and PC2 (N=200).

Group [a]	Demographics and nutritional status	Eating related symptoms	Food sensory experiences	Food sensory preferences	Motivation to eat
PC1 (+)	NRS intake score***	Low appetite***	Q8: nauseating aromas***	Q1: familiar foods**	Q45: forced eating***
Forced eating	Infectious medicine**	Early satiety***	Q17: change in taste desire*	Q5: small portions**	Q46: eat to overcome illness**
(n=102)	Oncology*	Nausea***	Q24: difficulty forming bolus***	Q18: mild flavours***	
		Vomiting***	Q25: film left in mouth***	Q19: not spicy***	
		Mouth pain***	Q29:my body needs a solid diet*	Q21: easy to eat***	
		Stomach pain***	Q32: consistency is important**	Q22: soft/fluid***	
		Problems chewing***	Q33: temperature problems***	Q23: moisture giving sauces**	
		Problems swallowing***	Q35: sensory specific satiety***		
		Diarrhea***	Q37: don't know what to eat***		
		Taste changes***	Q38: difficulty tolerating foods***		
		Throat pain**	Q39: redundant food choices***		
		Dry mouth*			
PC1 (–)	Energy balance***	NS	Q7: aroma increases appetite**	Q12: sour side-dishes*	Q41: enjoy food***
Enjoy eating	Protein balance***			Q13: savoury***	
(n=98)	Activity factor***			Q16: varied tastes**	
	Cardiology***			Q27: crispy/crunchy***	
	Male**			Q28: varied consistencies**	
	BMI*			Q34: varied dishes**	

PC2 (+)	NS	Early satiety***	Q6: appearance important***	Q2: garnished***	Q40: eat only when
High sensory variety		Stomach pain***	Q7: aroma increases appetite**	Q3: not mixed**	hungry*
(n=109)		Low appetite*	Q8: nauseating aromas***	Q5: small portions**	Q43: healthy eating**
			Q17: change in taste desire*	Q10: taste raw ingredients**	Q45: forced eating*
			Q20: taste important**	Q12: sour side-dishes***	
			Q25: film left in mouth*	Q16:varied tastes**	
			Q32: consistency important*	Q26: 'light foods'***	
			Q33: temperature problems*	Q27: crispy /crunchy***	
			Q35: sensory specific satiety***	Q28: varied consistencies***	
			Q37: don't know what to eat**	Q31: pleasantly satiating**	
				Q34: varied dishes***	
				Q36: varied daily***	
PC2 (–)	Male***	Problem chewing**	Q39: redundant food choices*	Q15: sweet**	NS
Low sensory variety	Infectious medicine*	Problem swallowing**		Q21: easy to eat*	
(n=91)				Q22: soft/fluid*	

[a] Patient segment group names are based on the authors' interpretation of the results.

Mann-Whitney U test within principal components, e.g., positive vs. negative side of PC1-axis PC1 (+) vs. PC1 (-)

NS = Non-significant, *p<0.05, **p<0.01, ***p<0.001

PC1 (-) patients were associated with milder symptoms as per an inverse association to eating-related symptoms. They were also related with enjoying their food (Q41), a preference for varied food sensory properties (Q16, Q34, and Q28), higher energy and protein balance, a higher activity factor, and the cardiology department.

PC2 segmented patients as *'high sensory variety'* (PC2 (+)) and *'low sensory variety'* (PC2 (-)). PC2 (+) was associated with a preference for varied food sensory properties (Q28, Q34, Q36, and Q16), which were also valued as being important (Q6, Q20 and Q32). Additionally, there were associations to early satiety, including sensory specific satiety (Q35); stomach pain; low appetite; and problematic food sensory experiences (Q8, Q35, Q37 and Q25). Patients with positive PC2 scores were also more female and preferred 'light foods' (Q26). Healthy eating (Q43); eating only when hungry (Q40); and forced eating (Q45) were also associated with PC2 (+). In contrast, PC2 (-) was associated with problems chewing and swallowing; a preference for sweet (Q15) and less varied foods (Q22 and Q39); being male and the infectious medicine department.

Patients were grouped according to their motivation to eat characterised by '*forced eating'* and *'enjoy eating'* (i.e., agreement with Q41 and/or Q45) and their energy and protein balance was assessed (Table 5). Patients that enjoyed eating had significantly higher energy and protein balance than patients that forced themselves to eat.

Table 5 – Energy and protein balance of patients grouped according to eating characterised by pleasure (Q41) and/or force (Q45) (N=194) [a]

	(N %)	Energy balance, % [b]	Protein balance, % [b]
Pleasure	68 (35)	103 (83 – 140)	95 (65 – 115)
Force	59 (30)	85 (65 – 112)	64 (50 – 90)
Pleasure and force	56 (29)	106 (86 – 134)	89 (64 – 118)
Neither pleasure nor force	11 (6)	87 (56 – 113)	68 (35 – 94)

[a] Patients were grouped based on whether or not they fully or partially agreed to Q41: "I enjoy my food." and/or Q45: "I often force myself to eat." 'Force' = solely agreed to Q45; 'Pleasure' = solely agreed to Q41; and 'Pleasure and force' = agreed both to Q41 and Q45; and 'Neither pleasure nor force' = neither agreed to Q41 nor Q45.
[b] Values expressed as median (IQR).
Kruskal-Wallis H tests: p = 0.015 for energy balance and p = 0.002 for protein balance.
Post-hoc paired comparisons (Mann-Whitney U tests with Bonferroni adjustments): Energy balance: 'Pleasure' *vs.* 'Force' p = 0.024; and Protein balance: 'Pleasure' *vs.* 'Force' p = 0.006 and 'Force' vs. 'Pleasure and force' p = 0.012. All other paired comparisons were not significant.

Sensitivity for the use of retrospective *vs.* prospective dietary and activity records (i.e., patients from *study 1 vs.* patients from *study 2, 3,* and *4*) as well as interviewer administering the questionnaire was examined in additional score plots. These score plots suggested no association to the model (results not shown).

Discussion

The current study is the most comprehensive to our knowledge to quantitatively investigate eating-related symptoms and food sensory needs and motivation to eat and adequacy of food intake in a heterogeneous group of patients at nutritional risk. Changes in patients' sensory and eating ability have however been described earlier, including problems such as low appetite,[20] early satiety,[21] chemosensory changes,[22] and dry mouth.[23] Almost half of the variance in energy and protein balance could be explained by a four-component PCA model of the patient food choice questionnaire data. This highlights the strong relationship between patients' eating-related symptoms, food sensory needs, motivation to eat, and adequacy of their food intake.

Low appetite and early satiety were the most common eating-related symptoms affecting 85% and 79% of patients at nutritional risk, respectively, with over half being 'very much' affected. Dry mouth and taste changes were also quite common affecting 67% and 58% of patients, respectively. Varying prevalence rates of these symptoms have been found in previous studies.[8,22-28] However, these studies typically included patients regardless of nutritional risk status. Prevalence for low appetite ranged from 10% to 71%,[8,22,24-27] early satiety from 28% to 51%,[22-25] dry mouth from 57% to 63%,[22-24] and taste changes from 28% to 75%[22,24,28] in different patient groups. Of the 15 investigated eating-related

symptoms, low appetite, early satiety, stomach pain, nausea, taste changes, and swallowing problems were found to be significantly associated with lower energy and/or protein balance. Energy intake has previously been found to be inversely related to lack of appetite, nausea, and early satiety in advanced cancer pateints.[28] Another study in a heterogeneous patient population also found positive associations between appetite and food intake.[8]

The largest majority of patients (94%) were fully or partially in agreement with the statement that an appetising appearance of their food was important for them to eat it. For most patients (87%), an appetising appearance involved a preference for small portions. This suggests potential benefit of serving small, visually appealing portions to patients at nutritional risk. Preferences related to the complexity of the appearance of foods varied between patients depending on their motivation to eat, e.g., 'forced eating' and 'eating to overcome illness' was associated with a preference for foods that appeared simple with few garnishes.

Taste of foods was viewed to be important to promote intake by 86% of patients and a preference for a variety of tastes in a meal was positively associated with energy and protein balance. Almost all patients (93%) agreed that it was important to be able to taste the raw ingredients of foods, whereas approximately three-quarters of patients disliked artificial flavours, such as the flavour of oral nutritional supplements. Compliance to oral nutritional supplements has been problematic in some studies, which is often attributed to unacceptable taste.[29-31]

Energy and/or protein balance was negatively associated with nauseating aromas, difficulty forming a bolus, and preference for 'light foods'. These factors offer opportunities for optimising food sensory quality to promote food intake in nutritional risk patients. For example, an improved selection of appetising, low odour intensity foods could perhaps help to promote intake in the approximately half of patients that were negatively affected by nauseating aromas. Also, patients with difficulty forming a bolus would be well suited for easy to eat, soft and fluid foods. However, food intake could perhaps be further promoted by developing foods with a variety of textures whilst still being easy to form a bolus (e.g., solid, crispy foods that melt in the mouth). Enriched, nutrient dense foods have been shown to improve intake in nutritional risk patients, whereas this study found that a preference for 'light foods' was associated with lower energy and protein balance.[12] Foods that are perceived to be 'light', but that are in fact nutrient dense, could perhaps help to promote intake in these patients.

A preference for familiar foods and foods tasting as preferred was also negatively associated with energy and protein balance. As found in the qualitative study,[10] patients were motivated to eat by the comfort of getting back to their usual food routines. However, familiar foods led to great disappointment when they did meet expectations due to changed sensory and/or eating ability. It was suggested that food intake could perhaps be promoted in these patients by developing familiar foods adjusted to compensate for their abnormal sensory and eating ability. In terms of motivation to eat by physiological comfort, many patients in the current study preferred foods that were refreshing and thirst quenching (82%) or pleasantly satiating (75%). Preference for foods that were pleasantly satiating was positively associated with protein balance.

The first principal component from the PCA showed a strong, negative correlation between Q41: 'I enjoy my food.' and Q45: 'I force myself to eat.' Enjoying eating was also associated with higher energy and protein balance and a preference for varied food sensory properties, whereas forced eating was associated with more severe eating-related symptoms and preferences for mild, familiar, and easy-to-eat foods. These results mirrored those from the qualitative study,[10] suggesting a stark contrast between patients that were motivated to eat by pleasure *vs.* survival. Additionally, the current study found that forced eating was associated with about 20% lower energy and protein balance than in patients that enjoyed eating. These findings suggest that more focus should be given to patients who force feed themselves.

Limitations of the study should also be considered when interpreting the results. Firstly, the

observational design of this study is not conducive for assessing causal relationships, such as influence of food sensory quality on adequacy of food intake. Also, caution should be taken when interpreting departmental associations since it is very difficult to differentiate between the potential effect of patients' diagnoses and treatments from the varying practice and focus on clinical nutrition of the different departments. It is also uncertain how generalisable the results are internationally and to what extent food culture might have an influence. Lastly, patients' responses might have been influenced by wanting to please the interviewer, such as regarding statements on healthy eating and eating after recommendations.

In summary, the PCA results support the segmentation of patients based on their motivation to eat by pleasure *vs.* survival corresponding to contrasting food sensory needs for awakened appetite through food variety *vs.* facilitated eating by food simplicity, respectively. Energy and/or protein balance was positively associated with a preference for a variety in tastes, sour side dishes, sour foods, savoury foods, and pleasantly satiating foods. On the other hand, energy and/or protein balance was negatively associated with nauseating aromas, difficulty forming a bolus, and preference for 'light foods', familiar foods, and foods tasting as preferred. Food intake could perhaps be promoted by developing foods for patients segmented by their motivation to eat, e.g., pleasure *vs.* survival, and aimed at fulfilling their contrasting food sensory needs, e.g., awakening appetite *vs.* facilitating intake. Further studies are however needed to determine whether food product development and improvement of food sensory quality based on these results can actually improve food intake in patients at nutritional risk.

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Appendix 6: Paper III

Effect of food-sensory-based nutritional care on intake, physiological function and quality of life: a randomised, assessor-blinded controlled trial in hospitalised patients at nutritional risk

Effect of food-based nutritional care on intake, physiological function and quality of life: a randomised, assessor-blinded controlled trial in hospitalised patients at nutritional risk

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Short title: Effect of food in patients at nutritional risk

Non-standard abbreviations:

- BIA, bioelectrical impedance analysis
- HGS, handgrip strength
- IQR, interquartile range
- LOS, length of stay
- NRS-2002, Nutritional Risk Screening-2002
- NS, not significant
- RT, reaction time
- SD, standard deviation
- SF-36, Short Form 36 health survey questionnaire

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Abstract

Background & Aims: Many hospital patients have insufficient food intake. This study aimed at evaluating the effect of food-sensory-quality-based nutritional care on intake and outcome.

Methods: Medical hospital patients at nutritional risk (NRS-2002) were randomised to individualised food-sensory-quality-based nutritional care (intervention) or usual care and nutritional advice (control) in an assessor-blinded controlled trial. Daily food intake and change in handgrip strength, reaction time, weight, and bioelectrical impedance (BIA) were assessed every 3-4 days in hospital. Quality of life (SF-36 questionnaire) was assessed after 28 days.

Results: The intervention group (N=42) had higher energy and protein balance than the control group (N=39) (energy: 111% *vs.* 93%, $p = 0.009$; protein: 96% *vs.* 82%, $p = 0.016$; mean % of requirements). Energy balance was ≥75% in 90% *vs.*70% ($p = 0.029$) and protein balance was ≥75% for 83% *vs.* 57% ($p = 0.028$) of intervention *vs.* control patients, respectively. The intervention *vs.* control group had improved handgrip strength after 3-5 days (mean 3.0 kg *vs.* 2.7 kg) and reaction time after 9-11 days (median -86 ms *vs.* -49 ms), which was positively associated with intake, but did not differ between groups.

Conclusions: The intervention improved food intake in patients at nutritional risk and physiological function improved within a few days of nutritional care.

Keywords: disease-related malnutrition in hospital, randomised controlled trial, food sensory quality, intake, physiological function, quality of life

Introduction

About a third of hospital admitted patients are at nutritional risk and will likely benefit from nutritional care to prevent or correct undernutrition.[1,2] However, the nutritional status of hospital patients often worsens during hsopitalisation[3] and nutritional risk has been shown to be an independent predictor of poor clinical outcome, including increased rates of complications and death, decreased likelihood to be discharged to home, and prolonged length of hospital stay.[2] Undernutrition is also related to reduced physiological function[4,5] and quality of life,[6] which has been shown to improve through adequate nutritional therapy.[4,7,8] For example, Christie et al.[4] found 20-40% impairments in skeletal and respiratory muscle function in undernourished hospital patients with inflammatory bowel disease as compared to age, sex, and height matched healthy controls. An effect of parenteral nutrition therapy in these patients was already apparent by the fourth day of nutritional therapy, including a significant improvement in handgrip strength (HGS) from a mean of 26 kg to 31 kg in four days.[4] Reaction time (RT) as a measure of cognitive function[9] has also been found to be sensitive to nutritional interventions in healthy individuals.[10,11]

The majority of patients at nutritional risk are dependent on predominantly food-based nutritional care to meet their nutritional requirements.[12] However, linking nutritional screening to effective nutritional care is a challenge in practice and many patients eat inadequately despite sufficient food provisions.[13,14] A Danish study[1] from about a decade ago found that intake in only about 25% of patients at nutritional risk covered ≥75% of their energy and protein requirements. The three main causes of inadequate nutritional care in this study included: 1) lack of guidelines and instructions for nutritional screening and therapy, 2) insufficient theoretical and practical knowledge of nutritional care among the nursing staff, and 3) patients' lack of appetite and unsuitability of hospital food.

Implementation of nutritional risk screening and nutritional care guidelines and training for nursing staff has been a focus over the past couple of decades in Denmark[15] and improving the suitability of hospital food was recognised as becoming increasingly important once the other issues had been addressed.[16] Therefore, qualitative and quantitative studies were recently conducted to investigate food sensory quality as perceived by patients at nutrition risk. A model of food sensory quality to promote intake in nutritional risk patients[17] and a patient food choice questionnaire[18] were developed. These studies provided the basis for the nutritional care intervention used of this study.

A randomised controlled trial by Johansen et al.[19] on the effect of nutritional intervention in hospital patients at nutritional risk found a shortened length of stay (LOS) in the intervention group, but only in patients that developed complications.[19] Also, a recent randomised controlled trial by Starke et al.[8] in hospital patients at nutritional risk found that individualised nutritional care improved clinical outcome and quality of life. Food intake played an important role in covering nutritional requirements in both of these studies.[8,19] However, the suitability of hospital food was not a focus and limited information was provided on the characteristics of the food that helped to improve intake. Future studies are required to investigate the characteristics of effective food-based nutritional care.

The present study aimed at investigating the effect of individualised, food-sensory-quality-based nutritional care compared to usual practice and general nutritional advice in hospital patients at nutritional risk. Outcome variables included energy and protein intake, physiological function (i.e., HGS and RT), and quality of life.

Materials and Methods

Trial design

This was a randomised, concealed allocation, assessor-blinded, controlled trial of food-based nutritional care during hospitalisation in medical patients at nutritional risk and analysed by intention-to-treat. Patients were individually randomised to one of two parallel groups with varying nutritional care regimens: current practice and general nutritional advice (control group) or individualised,

food-sensory-quality-based nutritional care consisting of appetising, energy- and protein-rich foods determined by the patient's food sensory needs[17,18] (intervention group). The primary outcome variable was average daily energy and protein intake. Change in physiological functions (i.e., HGS, RT and BIA) during hospitalisation and change in quality of life after a 28-day follow-up period were secondary outcome variables. The study was approved by the local Biomedical Ethics Committee for the Capital Region of Denmark and registered with ClinicalTrials.gov (NCT01240031).

Study setting

The study was conducted at Copenhagen University Hospital (Rigshospitalet), an acute-care, tertiary hospital in Denmark with 1,200 beds divided into units comprised of 15–20 beds. Nine units from the medical departments of cardiology, haematology, rheumatology, oncology, and infectious medicine participated in the study. The research team, lead by a PhD student in clinical nutrition and clinical dietitian (JMS), included MSc clinical nutrition and dietitian students, who were responsible for the nutritional care intervention, as well as a blinded outcome assessors.

The hospital food service offers three main meals, which are prepared by cook-chill, cook-freeze, and cook-serve in a central kitchen and served daily, buffet style according to a 5-week menu rotation. Three main diet types are available, including the 'hospital diet' with higher energy and protein density than the 'normal diet' and 'vegetarian diet'. Additionally, patients at nutritional risk can order from the dietitian-prescribed 'super diet', an à la carte menu of appetising, energy and protein-rich, warm and cold meals, snacks and side-dishes, which were specially developed to optimise nutritional and food sensory quality. Main meals are intended to fulfil two-thirds of nutritional requirements, whereas the remaining third is to be covered by microwaveable meals, snacks and beverages prepared in small kitchens on the units and served on demand.

Participants

All newly admitted patients from the participating departments were screened for nutritional risk (NRS-2002 $\geq$ 3).[20] NRS-2002 score is calculated by the sum of a 'nutritional score' of 0 to 3 (i.e., as per dietary intake in the past week, weight loss in the last 3 months and body mass index (BMI)), a 'severity of disease score' of 0 to 3 (i.e., reflecting increased protein requirements caused by stress metabolism), and a score of 1 for patients older than 70 years.[20]

Patients at nutritional risk were considered for inclusion in the study if they were 18 years of age or older, had an expected LOS in hospital of at least five days as per the patient's nurse and/or physician, could communicate in Danish or English, and gave informed, written consent to participate in the study. Patients were excluded from the study if they received or planned to start enteral or parenteral nutrition or could not eat normally; suffered from impaired cognitive function, mental health or physical function, impeding their ability to complete study measurements (e.g., acute disease or injury of the upper extremity affecting HGS); were terminally or acutely ill; had previously participated in the study; or shared a room with a study participant.

Patients that had electrical devices (e.g., implanted defibrillator, pacemaker) were excluded from measurements of bioelectrical impedance (BIA) as a safety precaution and patients with poor sight were excluded from the RT test, but were otherwise included in the study. Patients not found to be eligible for the study, such as due to nutritional risk status, were reassessed for inclusion in the study on a weekly basis during hospitalisation.

Baseline characteristics

After recruitment, baseline characteristics were recorded, including gender, age, department, diagnosis, HGS as percent of standard for sex and age,[21] nutritional status (i.e., weight, BMI, intake, weight loss and NRS-2002 scores), rescreening and hospital LOS at study start. Body weight was obtained by weighing and height was self-reported by the patient. All patients completed a patient food choice questionnaire,[18] including 15 questions on eating related symptoms (three-point scale) and 46

questions on food sensory needs of the appearance, aroma, taste, texture and consistency, temperature and variation of meals and motivation to eat (five-point Likert scale) at the start of the study.

Randomisation

Allocation to nutritional care intervention was done by computer generated, simple randomisation for the first twenty patients due to technical delays with the intended randomisation software and for the remaining patients, by minimisation randomisation stratified according to department, NRS-2002 intake score, and HGS as a percent of standard for age and sex[21] (i.e., < 50%, 50-75%, >75%). To ensure allocation concealment, research staff was blinded to the randomisation method and entered baseline characteristics into computer software for the study from which they could only see the allocated nutritional care. Following randomisation, patients and their nurses were informed about the nature of the nutritional care in the study, but it was not described in terms of being randomised to the control or intervention group.

Nutritional care interventions

Patients in the control group were given general nutritional advice at the start of the study as follows: 1) eat energy and protein-rich foods, e.g., high-fat dairy products, meat, eggs, nuts, sauce, dressing, butter; 2) eat small meals spread throughout the day, including snacks in the morning, afternoon and evening; and 3) drink energy and protein-rich beverages as opposed to water. Further advice was given in response to questions from patients, who were also informed of the sufficiency of their food intake from the dietary records. The nursing staff was responsible for the food given to control patients and could refer to a dietitian as per current practice.

In addition to the above advice, patients in the intervention group received individualised, food-sensory-quality-based nutritional care from the research team, who were all trained about food sensory quality to promote intake in patients at nutritional risk.[17,18] A nutritional plan, based on a nutritional assessment and the patient food choice questionnaire,[18] was developed, implemented and continually updated by the research staff. Appetising, energy- and protein-rich meals, snacks and beverages were provided as determined by the patient's food sensory needs and motivation to eat. This included the 'super diet'; regular snacks, such as marzipan treats, chocolates, candy, nuts, cheese and crackers, desserts and ice cream; high-fat dairy products; protein powder; and nutritious beverages, such as oral nutritional supplements, 'home-made' nutrition drinks and milk as opposed to juice, soft drinks, or water. Nutritional care was provided from morning to evening all days of the week. Detailed records were kept for each patient to ensure consistency in the nutritional care between consecutive work shifts of the research staff.

If an intervention or control patient's food intake was insufficient (i.e., < 75% of nutritional requirements for ≥ 3 days), without signs of improvement, the nursing staff were consulted, who determine whether enteral or parenteral nutrition should be started. If enteral or parenteral nutrition was started, patients were still followed in the study as per intention-to–treat. Patients that were prescribed parenteral or enteral nutrition by the department based on food intake <75% of nutritional requirements for weight maintenance for 3 days, as per current practice, were considered treatment failures.

Daily follow-up: energy and protein intake

Energy requirements were calculated by the factorial method (i.e., basal metabolic rate, determined by the Harris Benedict equation, multiplied by an activity factor and a stress factor), which has been used in liver cirrhosis patients[22] and evaluated in a heterogeneous group of patients.[23] Actual, measured weight was used in the calculation except for obese patients (BMI>30kg/m^2) in which an adjusted body weight, based on the metric Hamwi method, was used.[24] The average daily activity factor was determined by daily activity records for every 15 minutes of 'lying sleeping', 'lying awake', 'sitting', 'walking', and 'training' with corresponding activity factors of 0.9, 1.2, 1.3, 2.5, and 7, respectively.[23,25] Stress factors of 1.2, 1.3, and 1.4 were used for patients with fever of 38ºC, 39ºC, and 40ºC,

respectively.[26] Protein requirements were set at 18% of energy requirement in accordance with the elevated needs of patients as compared to healthy individuals and current practice at the hospital.

Daily dietary and activity records were completed prospectively by the patient and/or nursing staff, as per current practice. Records were checked for completeness by the research staff using 24-hour recall, especially if records could not be completed by the patient and/or nursing staff. Dietary recording was done using a form currently used in practice and customised for the hospital food service by using weighed reference portions for hospital menus and food items. Energy and protein content of hospital recipes, foods, and beverages was based on Danish nutritional data from the Master Cater System (Anova Data, Holte, Denmark). Portion size of food items was assessed visually in quartiles[27] and in millilitres for beverages and liquid food items. Energy and protein balance was calculated in terms of percent of estimated requirements met by the daily intake.

Daily follow-up also included recording of the patient's medical condition, treatments and procedures (e.g., complications, surgery, periods of fasting, home leave from hospital) and presence of oedema/ascites. Complications were entered from a list of complications with definitions based on Buzby et al.[28] The patient's discharge destination (i.e., home, nursing home, or death) and LOS were also recorded.

Measurement sessions: physiological function and weight

Physiological function and weight was measured in the patients at baseline prior to their nutritional care intervention and every 3 to 4 days thereafter until discharge from hospital. Measurements were completed by a trained outcome assessor blinded for the allocated intervention. Patients were also informed to not discuss their nutritional care with the outcome assessor.

Measurement sessions were performed at the bedside starting with weight followed by HGS, RT and lastly, BIA. Subsequent sessions were scheduled at the same time of day within a two-hour time frame and any deviations from the intended timing, cancellation of scheduled measurement sessions and the reasons for this were recorded. Measurement sessions took about 30 minutes to complete.

HGS was measured using GripTrack Hand Dynamometer (JTECH Medical, Salt Lake City, United States). Patients were tested on their dominant side, while seated, with their shoulder adducted, their elbow flexed 90°, and their forearm in a neutral position.[29] They were asked to hold this position and given further testing instructions. Standardised encouragement was given for each test. Maximal isometric hand grip strength was measured three times with the handle in the second position and about 15 seconds rest between trials. An average of the three trials was then calculated.

The Go/No-Go (5 stimuli, 2 targets) subtest of the Test for Attentional Performance version 2.1 (TAP 2.1; PsyTest, Herzoganrath, Germany) was used to measure RT. Patients were seated or sat up in bed in front of a laptop monitor, which was placed on their bedside table. They were instructed to react as accurately and quickly as possible to visual stimuli by pressing a button on their table with the index finger of their dominant hand. The Go/No-Go test involved 60 stimuli presented over 165 seconds during which patients were to react only to two out of five possible figures (i.e., two targets and five different stimuli). This task tested their ability to perform under a time pressure whilst suppressing inappropriate behaviour responses. Results of the test included their median response time in milliseconds (ms), and total errors and omissions during the test.

BIA was performed using EFG (Akern/RJL Systems, Florence, Italy), which is a whole body (hand-to-foot), single frequency analyser producing an alternating current of 330 μA at 50 kHz. Patients were measured in the supine position with their arms spread 30º from their torso and legs 45º apart. Electrodes were placed in a tetra polar arrangement on the dorsal surface of the right hand and wrist and the anterior surface of the right food. If obstructions, such as an intravenous cannula, prevented proper electrode placement, the left side was measured instead. The same side of the body

was always used for the repeated measurements. The BIA measurements included reactance, resistance, capacitance, and phase angle. Presence of oedema (e.g., pitting on back of ankles) and/or ascites was also noted.

Quality of life

Quality of life was measured at baseline and on the 28th study day using the Short Form 36 Health Survey version 2.0 (SF-36v2™), comprised of 36 questions on functional health and well-being.[30] The SF-36 questionnaire was completed independently by the patient or, if needed, with assistance by the outcome assessor. Follow-up SF-36 questionnaires were returned by post or, if necessary, were completed by telephone with the outcome assessor for patients that were discharged prior to the 28th study day. The Quality Metric Health Outcomes™ Scoring Software 2.0 was used to compute the eight-scale profile (i.e., physical functioning, role physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health scales) and psychometrically-based physical and mental health component summary scores.

Statistical analysis

Sample size was calculated according to a power of $1\text{-}\beta = 0.9$ and significance level of $\alpha = 0.05$. An effect size on the primary outcome variable, energy intake, of 1831 kJ was based on the results from a comparable intervention study.[8] On the other hand, an effect size on the secondary outcome variable, HGS, of 3.8 kg was based on a pilot study.[31] This effect size on HGS was found when splitting patients from the pilot study into two equal groups, according to those with the highest *vs.* lowest energy balance with an intake difference of 2554 kJ. With a drop-out percent of 20% and standard deviations based on the pilot-study, it was estimated that 30 and 36 patients were required per study group to be able to show an effect on energy intake and HGS, respectively.

Analyses were to be done by intention-to-treat, i.e., including all patients retained in the group to which they were allocated regardless of protocol violations. However, there were some missing follow-up observations, including 5% for energy and protein balance, 16% for HGS and weight, 32% for RT, 48% for BIA, and 40% for SF-36 (see Fig 1). The analyses done for energy and protein balance, HGS, weight, LOS, discharge destination and complications were considered less cause for concern for doing an intention-to-treat analysis as per a low rate of or no missing observations. On the other hand, the analyses done for RT, BIA and SF-36 were more reflective of complete case analysis due to a higher number of missing observations. These analyses were therefore interpreted with more caution and baseline characteristics of patients analysed versus patients with missing observations were compared and suspected interactions were tested using generalised linear models. Also, measurement sessions with incomplete physiological function results (e.g., RT, BIA) were analysed by the next observation carried backwards or the last observation being carried forward as specified in the results section. Per-protocol analysis, excluding treatment failures (i.e., patients that received enteral or parenteral), was done for comparison.

Descriptive statistics were presented as mean ± standard deviation (SD) or median (interquartile range (IQR)) for parametric or nonparametric continuous variables, respectively, and as number (percent) (N (%)) for categorical variables. The Student's t /Mann-Whitney U test, paired-t/Wilcoxon signed-rank test and Pearson/Spearman rank correlation test were used for parametric/nonparametric independent comparisons (e.g., between study groups), paired comparisons (e.g., within study groups) and correlation analyses, respectively. Categorical data was assessed using Pearson's chi-square or Fisher's exact test. Department, primary diagnosis and NRS-2002 intake categories were treated as dummy variables. ANOVA and Kruskal Wallis were used to compare multiple groups for parametric and nonparametric data, respectively, followed by post-hoc paired Bonferroni corrected comparisons. Potential interactions were further assessed by including the interaction as a variable in a generalised linear model. Analysis of change in physiological function and weight was done for changes from baseline to 3-5 days, 6-8 days, 9-11 days, 12-14 days and final (i.e., last measurement session). Statistical analyses were

performed using SPSS (version 17.0, SPSS Inc, Chicago, USA) and non-significant results were denoted as NS.

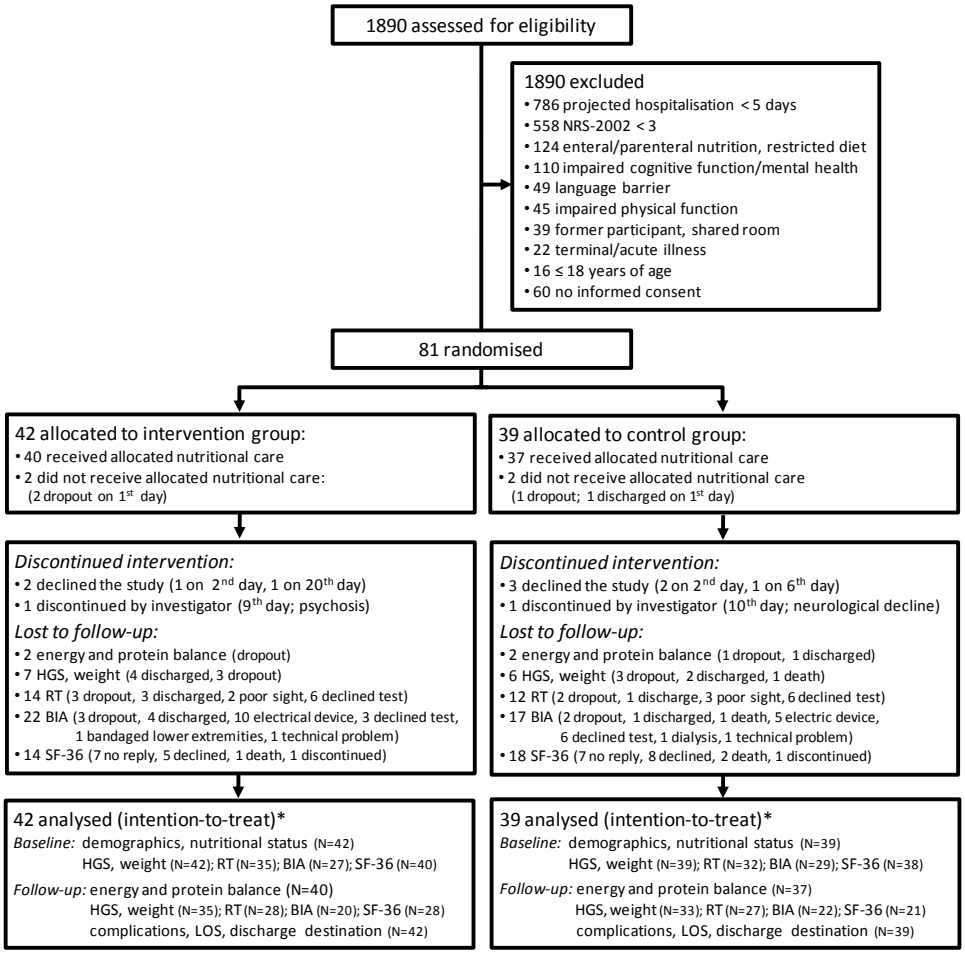

Fig 1 – Flow diagram of the study including enrolment, randomisation, treatment allocation, follow-up and analysis; HGS, handgrip strength; RT, reaction time; BIA, bioelectrical impedance analysis; SF-36, Short Form 36 health survey questionnaire¸ LOS, length of stay. * See section '2.1 Statistical analysis' for a more detailed description of the intention-to-treat analysis.

Table 1 – Patient demographics and nutritional status at baseline (N=81).

	Intervention group (N=42)	Control group (N=39)
Males, N (%) *	22 (52 %)	22 (56 %)
Age, years [a]	60.6 ± 14.0	60.5 ± 16.6
Department, N (%) *		
Cardiology	13 (31 %)	12 (31 %)
Infectious medicine	12 (29 %)	12 (31 %)
Oncology	7 (17 %)	7 (18 %)
Haematology	7 (17 %)	5 (13 %)
Rheumatology	3 (7 %)	3 (8 %)
Malignant, N (%)	14 (33 %)	13 (33 %)
Primary diagnosis, N (%) [c]		
Infection	11 (26 %)	15 (38 %)
Cardiovascular	12 (29 %)	8 (21 %)
Solid tumor	8 (19 %)	6 (15 %)
Haematology	6 (14 %)	5 (13 %)
Observation	2 (5 %)	1 (3 %)
Pneumonia	1 (2 %)	1 (3 %)
Other medical diagnoses	2 (5 %)	3 (8 %)
Handgrip strength, % [b, d] *	62 (38 – 109)	61 (44 – 87)
Body weight, kg [a]	74.5 ± 17.2	76.6 ± 21.1
BMI, kg/m² [a]	25.4 ± 6.1	25.4 ± 5.7
Intake 0-25%, N (%) [e] *	9 (21 %)	9 (23 %)
Intake 25-50%, N (%) [e] *	17 (40 %)	13 (33 %)
Intake 50-75%, N (%) [e] *	13 (31 %)	11 (28 %)
Intake >75%, N (%) [e] *	3 (7 %)	6 (15 %)
Weight loss ≥ 5%, N (%) [f]	29 (69 %)	25 (64 %)
NRS-2002: nutritional score [b]	3 (2 – 3)	3 (2 – 3)
NRS-2002: severity of disease score [b]	1 (1 – 1)	1 (1 – 1)
Rescreening, N (%) [g]	11 (26 %)	13 (33 %)
LOS at baseline, days [b, h]	4 (2 – 6)	5 (3 – 7)

Values shown as mean ± SD [a], median (IQR) [b] or N (%); Student's t, Mann-Whitney U, and Pearson's chi-square / Fisher's exact tests, respectively: NS.

[c] Diagnoses were entered from a list of categories based on Sorensen et al.[2]

[d] Mean handgrip strength at baseline as a percent of normative handgrip strength for age and sex.[21]

[e] Patients with dietary intake 0-25%, 25-50% or ≥75% of normal requirements for weight maintenance in the week prior to screening by NRS-2002.

[f] Patients with weight loss ≥ 5% of body weight within the 3 months prior to screening by NRS-2002.

[g] Patients assessed for inclusion in the study by NRS-2002 rescreening conducted ≥ 1 week after admission to hospital.

[h] Length of stay in hospital at baseline.* Variables included in the minimisation randomisation.

Results

Study flow

A total of 1,890 patients were assessed for enrolment from April to December 2010, many of which were ineligible because of projected hospitalisations of less than five days (42%) and lack of nutritional risk status (30%), among other reasons as outlined in Fig 1. Of the 141 patients invited to the study, 81 consented to participate and 60 declined, mostly due to a lack of interest or capacity to participate. Randomisation allocated 42 and 39 patients to the intervention group and control group, respectively. Two intervention patients and two control patients did not receive their allocated nutritional care because of declining participation in the study or discharge from hospital at baseline.

A detailed summary of lost to follow-up of patients is given in Fig 1. Two intervention patients and three control patients received nutritional care, but withdrew during the study. Patients that dropped-out typically found the study follow-up to be too demanding. An intervention patient and a control patient were removed from the study by the investigator due to development of psychiatric conditions that greatly impeded their participation (i.e., alcoholic psychosis and acute neurological deterioration with apraxia and aphasia, respectively). An intervention patient with rheumatoid arthritis of the hands in remission was falsely included, but retained in the study as per intention-to-treat. Also, there were two incidents following enrolment in which an intervention patient and control patient shared a room for 12 to 18 days, which was unavoidable due to space issues.

Baseline characteristics

The patients' demographics and nutritional status at the start of the study, including gender, age, department, primary diagnosis, HGS, nutritional status, and LOS in hospital as presented in Table 1, did not differ between study groups. Mild to moderate oedema and/or ascites was present in 29% of intervention patients and 21% of control patients at baseline (NS between study groups). Baseline HGS, RT, BIA and quality of life (SF-36) were also not found to be statistically different between intervention patients and control patients as shown in Table 4 and Table 5.

Energy and protein balance

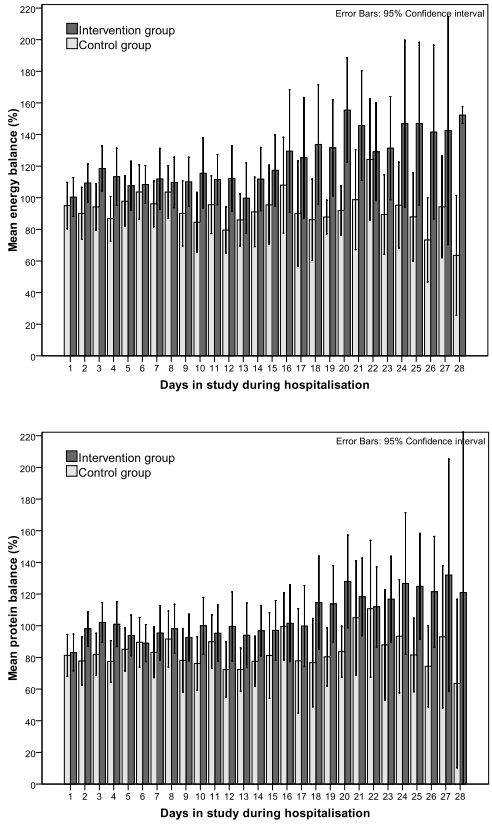

Fig 2 – Mean daily percent energy (A) and protein (B) balance during the study period in hospital for the intervention and control groups as depicted by the light and dark grey bars, respectively.

Fig 2 shows the mean daily energy and protein balance of intervention patients and control patients during the study period, which was significantly higher in the intervention group compared to the control group as given in Table 2. Energy balance was ≥ 75% for 90% of intervention patients and 70% of control patients ($p = 0.029$), whereas protein balance was greater ≥ 75% for 83% of intervention patients and 57% of control patients ($p = 0.028$). In patients with intake <75% of requirements the week prior to the study, significantly more intervention patients (89%) than control patients (66%) improved

their intake to ≥ 75% energy balance during the study (p = 0.015). Energy balance was significantly higher than protein balance in both study groups (p < 0.001). Energy and protein intake was significantly higher in the intervention group than the control group (Table 2).

Table 2 – Energy and protein intake and balance during the study period in hospital (N=77).

	Intervention group (N=40)	Control group (N=37)	p
Energy intake (kJ/day)	8051 ± 2222	6763 ± 2061	0.010
Protein intake (g/day)	73.8 ± 21.2	63.1 ± 21.3	0.031
Energy balance (%) [a]	111 ± 27	93 ± 31	0.009
Protein balance (%) [a]	96 ± 31	82 ± 28	0.016

Values shown as mean ± SD.
[a] Total energy/protein intake expressed as a percent of total estimated energy/protein requirements.

Nutritional care intervention: energy and protein intake

Intervention patients and control patients received nutritional care for 8 (4 – 20) and 10 (7 – 14) median (IQR) days during the study period in hospital (NS between groups). Daily dietary and activity records were completed for all patients that received their allocated nutritional care (N=77) and not including four patients that were discharged from the hospital or dropped out on the first day of the study (Fig 1). Dietary recording methods were not significantly different between intervention *vs.* control patients (i.e., dietary recording 80% *vs.* 70%; 24-hour recall 13% *vs.* 16%; and mixed dietary recording and 24-hour recall8% *vs.* 14%, respectively). Six patients in the control group (16%) were referred to a dietitian.

Mean calculated energy and protein expenditure was mean ± SD 7399 ± 1544 kJ/day and 77.9 ± 16.2 g protein/day in the intervention group and 7442 ± 1609 kJ/day and 78.3 ± 16.9 g protein/day in the control group (mean ± SD (IQR); energy: NS; protein: p = 0.048). Average daily activity factor was a mean ± SD of 1.17 ± 0.07 for intervention patients and 1.15 ± 0.06 for control patients. Fever (≥ 38 ºC) was present is 33.3 % and 25.6 % of intervention patients and control patients, respectively. Fever lasted for a median (IQR) of 16 (7 – 22) % and 16 (8 – 56) % of the time in the study in intervention patients and control patients with fever, respectively. Energy and protein expenditure, activity factor, and incidence of fever were not significantly different between study groups.

A comparison of the food-based nutritional care provided to the intervention group and control group is given in Table 3. In terms of meals, coverage of energy and protein requirements by lunch and snacks was significantly greater in the intervention group compared to the control group. As for food items, the intervention group's intake from the 'super diet', desserts, 'marzipan, candy, and nuts' and ice cream covered a significantly higher percentage of energy and protein requirements than the control group.

Protein intake from snacks as a percent of total protein intake was found to be positively correlated to energy balance (p = 0.013). Furthermore, percent of energy and protein intake from 'marzipan, candy, and nuts' was found to be positively correlated to energy balance (p = 0.005 and p = 0.004) and protein balance (p = 0.041 and p = 0.033). There was also a positive correlation between energy balance and percent of energy and protein intake from cream (i.e., 9% – 38% fat) (p = 0.015 and p = 0.013) as well as percent of energy and protein intake from ice cream (p = 0.029 and p = 0.019). In contrast, energy intake from 'juice, and soft drinks' was negatively correlated to protein balance (p = 0.016).

Intervention patients covered significantly more of their energy and protein requirements from normal food (i.e., excluding enteral and parenteral nutrition, protein powder and oral nutritional supplements) compared to control patients (energy: 98 ± 28% *vs.* 81 ± 29% (p = 0.039); protein: 82 ± 24% *vs.* 70 ± 28% (p = 0.040), mean ± SD). Enteral nutrition was used in three intervention patients and two control patients and parenteral nutrition was used in one control patient. Enteral and parenteral nutrition covered a median (IQR) of 8 (4 – 9) % of energy and 8 (3 – 11) % of protein requirements in intervention patients (n=3) *vs.* 21 (2 – 27) % of energy and 23 (2 – 28) % of protein requirements in

control patients (n=3) that received artificial nutrition, which was not significantly different between study groups. Analyses of energy and protein balance and intake between study groups were conducted without these patients that received artificial nutrition (i.e., treatment failures), which did not significantly change the results. Oral nutritional supplements covered a median (IQR) of 21 (7 – 28) % *vs.* 10 (4 – 19) % of energy and 24 (7 – 30) % *vs.* 9 (3 – 23) % of protein needs in the 58% of intervention *vs.* 68% of control patients that consumed them (NS between study groups). As high as 60% of energy and protein requirements were covered by oral nutritional supplements. Protein powder was used in no control patients and four intervention patients that had difficulty meeting their protein requirements and were willing to try it, covering from 1% to 46% of their protein needs (p = 0.05 between study groups). Comparing this to normal food items, maximum coverage of protein requirements was ≥25% for milk and cream (40%), yoghurt (39%), 'homemade' nutrition drinks (28%), cheese (25%) and desserts (25%).

Physiological function and weight

A total of 286 measurement sessions of physiological function and weight were conducted. This corresponded to a median (IQR) of 3 (2 – 5) *vs.* 4 (2 – 5) measurement sessions per intervention *vs.* control patients, respectively (NS between study groups). Only about a tenth of measurement sessions had to be rescheduled to a following day because of treatments (7%), patient's request (4%), or study capacity (1%). Some baseline and final tests were incomplete due to time constraints or patients declining the test. Therefore, the next observation was carried backward (RT: n=10; BIA: n=6) or the last observation was carried forward (HGS: n=1; RT: n=7, BIA: n=7) for inclusion in the analysis. Results for the measurements taken at different time points, including p-values, are outlined in Table 4.

Change in body weight was not significant within or between study groups from baseline to final. Oedema and/or ascites during the study period tended to improve in more intervention pateints than control patients (19% *vs.* 8%), whereas it tended to worsen in more control patients than intervention patients (23% *vs.* 12%) (NS between groups). An ANOVA of weight change from baseline to final was significant for patients grouped according to development in their oedema/ascites (i.e., increased: 1.0 ± 3.6 kg, stable: -0.6 ± 2.4 kg, decreased: -3.1 ± 5.1kg; p = 0.008) and post-hoc pairwise comparisons found the difference between patients with improved *vs.* worsened oedema/ascites to be significant (Bonferroni corrected: p = 0.007).

HGS improved significantly within both the intervention group and control group from baseline to final, but this change was not significantly different between study groups. Significant improvements in HGS could already be seen after 3-5 days (3.0 ± 7.3 kg and 2.7 ± 5.5 kg) and after 6-8 days (3.1 ± 5.3 kg and 3.9 ± 8.7 kg) in the intervention group and control group, respectively, as well as after 12-14 days (1.3 ± 1.4 kg) in the control group (see Table 4 for p-values). Average daily energy and protein intake during the first three days in the study correlated with change in HGS from baseline after 3-5 day (energy: r = 0.37, p = 0.006; protein: r = 0.35, p = 0.012). Furthermore, average daily energy and protein intake from the fourth to the sixth day in the study correlated with change in HGS from baseline after 6-8 days in the study (energy: r = 0.45, p = 0.002; protein: r = 0.39, p = 0.008).

RT speed improved and errors decreased significantly in both groups from baseline to final. There were no significant difference between groups for RT apart for a significantly greater improvement in RT at 6-8 days in the control *vs.* intervention group (median (IQR) -54 (-134 - -22) *vs.* -16 (-31 – 3), p = 0.02). Improvement in RT was significant for both the intervention *vs.* control group at 9-11 days (median (IQR) -86 (-223 - -32) *vs.* -49 (-148 – 12), NS between groups; see Table 4 for p-vales within groups). Energy and protein balance for the seventh to the ninth day in the study was negatively correlated with change in RT from baseline to 9-11 days in the study (energy: r = -0.441, p = 0.045; protein: r = -0.429, p = 0.052). Significant reduction in RT errors at specific time points was only seen in the intervention group at 9-11 days and a trend of reduction in errors was seen at 6-8 days in the

intervention group (p = 0.057). About a third of patients (intervention: 33%, control: 31%) were missing a follow-up RT. Demographic characteristics and nutritional status (i.e., variables in Table 1) and RT results at baseline were not significantly different in patients with RT lost to follow-up except that patient missing a follow-up RT were older (66.9 ± 16.9 *vs.* 57.5 ± 13.5, p = 0.009). Twelve patients declined the RT test of which four tried and gave-up, whereas eight lacked the energy or time to attempt the test. Five additional patients were unable to conduct the RT test because of poor or declining eyesight. Baseline RT was missing and the next observation 1-5 days later was carried backward for 7 intervention patients and 3 control patients. Excluding these patients from the RT analyses did not significantly change the results. Also, the final RT was missing and the last observation was carried forward for six control patients and one intervention patient.

Change in BIA, including resistance, reactance, phase angle and capacitance, was not significantly different within or between study groups from baseline to final and at specific periods between measurements. However, 52% of intervention patients and 44% of control patients were missing follow-up BIA. This was mostly due to BIA not being measured in cardiology patients with new electronic devices and also being the last measurement taken, some patients declined BIA due to lack of time or energy.

Quality of life

The SF-36 questionnaire was filled out independently, as opposed to interviewer administered, in 76% of intervention patients and 72% of control patients (NS between groups). All patients, except for two in the intervention group, completed SF-36 at baseline, whereas more intervention patients (67%) completed the follow-up SF-36 than control patients (54%) (NS between groups). Patients missing a follow-up SF-36 in the intervention *vs.* control group were compared for differences in their baseline demographics and nutritional status (i.e., variables in Table 1), SF-36 scores, rate of complications, LOS, and discharge destination. Control *vs.* intervention patients missing a follow-up SF-36 had lower general health scores at baseline (39.8 ± 21.5 *vs.* 54.4 ± 16.8 mean ± SD, p = 0.047), were discharged more frequently to home (86% *vs.* 44%, p = 0.017), and were less likely to be in hospital at 28 days in the study (7% *vs.* 39%, p = 0.047). The follow-up SF-36 was completed on the 28^{th} ± 2 and 28^{th} ± 5 day of the study in the intervention group and control group, respectively.

The SF-36 results at 28 day follow-up were not significantly different between study groups. However, patients in the control group had significant improvements in bodily pain, general health and mental health, whereas role-emotional improved, but general health worsened in the intervention patients during the study period as presented in Table 5. When comparing change in SF-36 between study groups, increases in general health and physical component summary scores were significantly higher in the control group than in the intervention group. However, based on the lower general health scores and higher likelihood to be discharged home in the control patients with SF-36 lost to follow-up, the effect of these potential interactions was assessed using general linear models with study group, discharge home, and the interaction term (study group x discharge home). Effect of the study group was no longer significant in the model for general health (NS for all variables) and the model for physical component score (NS for all variables).

When comparing adequacy of intake to change in SF-36 during the study period, energy and protein balance positively correlated with change in role-emotional (energy balance: r = 0.329, p = 0.025; protein balance: r = 0.314, p = 0.034) and change in mental health (energy balance: r = 0.289, p = 0.048; protein balance: r = 0.359, p = 0.014), but negatively correlated to change in general health (energy balance: r = -0.295, p = 0.042). As for comparison of adequacy of intake and baseline SF-36, energy and protein intake and balance were positively correlated to general health at baseline (energy balance: r = 0.286, p = 0.012; protein balance: r = 0.329, p = 0.004; energy intake: r = 0.325, p = 0.004; protein intake: r = 0.344, p = 0.002) and mental health at baseline (protein intake: r = 0.283, p = 0.04).

Table 3 – Nutritional care intervention: coverage of energy and protein requirements by meals, food items and beverages during the study period in hospital (N=77).

	Intervention group (N=40)		Control group (N=37)	
	Energy (%) [c]	**Protein (%) [c]**	**Energy (%) [c]**	**Protein (%) [c]**
MEALS				
Breakfast [a]	13 ± 7	10 ± 7	12 ± 7	9 ± 6
Lunch [a]	17 ± 8*	15 ± 7*	12 ± 8*	11 ± 7*
Supper [a]	22 ± 9	23 ± 10	18 ± 10	20 ± 11
Snacks [b, d]	12 (5 – 23)*	6 (2 – 12) *	6 (4 – 11)*	3 (2 – 6) *
Beverages & liquids [a, e]	45 ± 19	41 ± 17	42 ± 24	37 ± 23
FOOD ITEMS				
'Super diet' [b, f]	7 (0 – 24)***	7 (0 – 22)***	0 (0 – 2)***	0 (0 – 2)***
Desserts [b]	12 (6 – 17) ¤	4 (1 – 5)*	7 (4 – 13) ¤	2 (1 – 3)*
Marzipan, candy, nuts [b]	2 (0 – 8)*	1 (0 – 7)*	0 (0 – 1)*	0 (0 – 1)*
Dairy products [a, g]	30 ± 15	33 ± 16	25 ± 14	29 ± 16
Cheese [b]	3 (0 – 4)	5 (0 – 8)	2 (1 – 3)	3 (1 – 7)
Ice cream [b]	1 (0 – 4)¤	0 (0 – 2)*	0 (0 – 1)¤	0 (0 – 1)*
Butter [b]	2 (1 – 5)	0 (0 – 0)	3 (1 – 4)	0 (0 – 0)
Milk, cream [b]	8 (2 – 14)	11 (2 -20)	6 (2 – 10)	9 (3 – 15)
Yoghurt [b]	6 (2 -9)	6 (2 – 11)	5 (1 – 7)	6 (1 – 8)
'Homemade' nutrition drink [b, h]	3 (0 – 7)	3 (0 – 9)	2 (0 – 6)	2 (0 – 7)
Oral nutritional supplements [b]	3 (0 – 25)	3 (0 – 25)	4 (0 – 14)	3 (0 – 18)
Juice, soft drinks [b]	5 (2 -11)	0 (0 – 0)	7 (3 – 10)	0 (0 – 0)

Values shown as mean ± SD [a] or median (IQR); [b]

Student's t-test or Mann-Whitney U (between groups): ¤$p < 0.04$, *$p < 0.02$, **$p < 0.01$ ***$p < 0.001$.

[c] Total energy/protein intake from meals, food and beverages as a percent of total energy/protein requirements during the study period.

[d] Solid food items consumed between main meals.

[e] Beverages and liquid food items consumed during and between meals and enteral and parenteral nutrition.

[f] Appetising, energy and protein rich meals, desserts and snacks prescribed for patients at nutritional risk.

[g] Cheese, ice cream, butter, milk, cream, yoghurt and 'home-made ' nutrition dirk; does not include dairy products when used as an ingredient in mixed dishes.

[h] Energy and protein rich milk-based nutrition drinks made by the hospital kitchen and Arla Foods (i.e., Protin©).

Table 4 – Change in weight, handgrip strength, reaction time and phase angle during the study period.

Variable	Group	Baseline	3-5 days	6-8 days	9-11days	12-14 days	Final [d]	Δ final - baseline
N	Intervention	42	28	20	13	10	35	35
	Control	39	25	27	16	12	33	33
Weight, kg [a]	Intervention	74.5 ± 17.2	72.9 ± 15.5	77.0 ± 18.7	72.9 ± 16.1*	68.3 ± 19.0	73.7 ± 17.7	-1.0 ± 3.5
	Control	76.6 ± 21.1	79.8 ± 23.8	77.7 ± 23.8†	83.3 ± 22.9	84.6 ± 23.5	76.8 ± 22.7	-0.4 ± 3.2
HGS, kg [a]	Intervention	24.3 ± 13.1	25.0 ± 15.2¤	28.0 ± 14.0‡	26.8 ± 13.9	25.1 ± 12.9	25.9 ± 14.1°°°	1.7 ± 6.2
	Control	23.9 ± 8.0	25.7 ± 8.0†	25.5 ± 8.3†	25.2 ± 9.4	31.4 ± 14.5‡	26.0 ± 8.5**	2.1 ± 9.8
N	Intervention	35	16	12	10	6	28	28
	Control	32	15	17	11	7	27	27
RT, ms [b]	Intervention	657 (581 – 766)	655 (570 – 741)	603 (531 – 678)	573 (537 – 654)‡	614 (513 – 658)	601 (527 – 668)°°	-58 (-136 – 1)
	Control	628 (565 – 748)	560 (536 – 677)°°	526 (505 – 650) °°°	549 (513 – 602)‡	512 (481 – 547)†	549 (504 – 664) ***	-57 (-108 - -20)
RT, errors [b, c]	Intervention	3.0 (0 – 13.0)	0 (0 – 1.5)	0 (0 – 1.5)	0 (0 – 1.5)†	0.5 (0 – 2.0)	0 (0 – 3.0)**	-1.5 (-5.5 – 0)
	Control	2.5 (0 – 11.0)	1.0 (0 – 7.0)	0 (0 – 4.0)	0 (0 – 0)	0 (0 – 0)	1.0 (0 – 2.0)‡	-1.0 (-4.0 – 1.0)
N	Intervention	27	17	12	10	5	20	20
	Control	29	14	18	11	7	22	22
PA, ° [a]	Intervention	4.5 ± 1.2	5.1 ± 2.6	4.6 ± 0.9	4.3 ± 1.2	4.0 ± 1.3	4.7 ± 2.5	0.5 ± 2.4
	Control	4.1 ± 0.9	4.7 ± 1.5	4.4 ± 1.7	4.0 ± 0.8	4.3 ± 1.0	4.1 ± 1.5	0.2 ± 0.2

Values shown as mean ± SD [a] or median (IQR) [b]; Mann-Whitney U; HGS: handgrip strength, RT: reaction time, PA: phase angle.

[c] Total count of both errors and omissions during the RT test.

Paired t-test from baseline within groups: *$p < 0.05$, ¤$p < 0.04$, †$p < 0.03$, ‡$p < 0.02$ **$p < 0.01$, °°$p < 0.005$, °°°$p < 0.002$, ***$p < 0.001$

Student's t-test between groups of Δ final - baseline: NS

[d] Last follow-up measurement session typically taken just prior to discharge from hospital or at the end of the study follow-up period.

Table 5 – Change in quality of life (SF-36) after 28-days follow-up.

SF-36 scores	**Group**	**Baseline** [a]	**Follow-up** [a]	**Difference** [b]
	Intervention	N = 40	N = 28	N = 28
	Control	N = 38	N = 21	N = 21
Physical function	Intervention	46.0 ± 27.9	49.5 ± 28.1	2.7 ± 32.0
	Control	39.2 ± 29.7	46.6 ± 27.2	2.3 ± 40.7
Role-physical	Intervention	23.1 ± 27.9	14.1 ± 24.7	-7.2 ± 25.9
	Control	20.4 ± 27.0	20.0 ± 26.9	3.4 ± 28.5
Bodily pain	Intervention	37.5 ± 33.5	43.6 ± 32.3	4.1 ± 31.1
	Control	35.2 ± 35.4 †	51.4 ± 31.4 †	18.3 ± 32.0
General health	Intervention	47.5 ± 22.1°	44.9 ± 24.3°	-5.8 ± 12.8**
	Control	49.7 ± 20.5‡	54.2 ± 23.7‡	8.6 ± 15.5**
Vitality	Intervention	31.3 ± 22.5	33.6 ± 22.8	1.3 ± 24.2
	Control	32.1 ± 20.3	39.0 ± 22.4	4.6 ± 18.8
Social functions	Intervention	61.9 ± 31.5	52.2 ± 30.6	-8.5 ± 37.0
	Control	57.6 ± 32.2	53.6 ± 34.7	-6.9 ± 34.0
Role-emotional	Intervention	43.5 ± 36.5#	59.9 ± 40.6#	16.7 ± 42.4
	Control	46.6 ± 42.6	42.5 ± 39.3	-2.9 ± 33.1
Mental health	Intervention	59.0 ± 18.0¤	65.4 ± 16.9¤	4.5 ± 17.3
	Control	53.3 ± 22.0	65.2 ±24.1	9.0 ± 17.5
Physical component summary	Intervention	33.5 ± 10.6	31.7 ± 10.0	-2.3 ± 8.8*
	Control	32.2 ± 9.5	35.2 ± 10.3	3.9 ± 10.7*
Mental component summary	Intervention	39.0 ± 11.0	42.8 ± 11.3	3.4 ± 11.0
	Control	38.8 ± 15.0	40.2 ± 15.4	0.2 ± 12.6

Values shown as mean ± SD.

[a] Paired t-test of baseline and follow-up within groups: †p = 0.019, ‡p = 0.02, ¤p = 0.033, °p = 0.024 #p = 0.051

[b] Student's t-test of difference between groups: *p = 0.033, **p = 0.001

Daily follow-up, complications, length of stay and discharge destination

Rate of complications and surgeries, periods of fasting, and home leave were not significantly different between study groups. Complications occurred in 16% of patients: six in the intervention group (i.e. 15%; bacteriaemia (1), gastrointestinal bleeding (1), intraperitoneal abscess (1), respiratory failure grade 2 (1), skin infection (1), urinary tract infection (1)) and seven in the control group (i.e., 18%; bacteriaemia (1), gastroenteritis (3), kidney failure grade 2 (1), respiratory arrest (1), urinary tract infection (1)). Minor surgeries were done in two intervention (i.e., cervical spine and ankle revision and defibrillator implantation) and one control patient (i.e., pulmonary artery catheter and stent removal). Fasting for procedures occurred for short periods in 24% of intervention patients and 41% of control patients on a median (IQR) of 14 (5 – 33) % and 10 (8 – 13) % of days in the study, respectively. A fifth of the patients, eight intervention patients and eight control patients, were on home leave from hospital for median (IQR) 23 (9 – 47) % and 38 (37 – 45) % of the study period, respectively.

Length of stay in hospital was 12 (8 – 29) *vs.* 17 (12 – 24) median (IQR) days for intervention *vs.* control patients, respectively, which was also not significantly different between study groups. However, significantly more intervention patients than control patients were discharged home (86% *vs.* 54%) as opposed to discharged to a nursing home (0% *vs.* 5%), were transferred to another hospital or remained in hospital (12% *vs.* 36%) or died (2% vs. 5%) within the 28-day follow-up period for the study (Fisher's exact test: home: $p = 0.002$, hospital: $p = 0.011$, nursing home: NS, death: NS). Patients that were discharged to home did not have significantly different energy or protein intake or balance during the study period compared to patients that were not discharged to home during the study period.

Discussion

This study demonstrated a positive effect of individualised, food-sensory-quality-based nutritional care on food intake and rapid improvements in physiological function, including HGS and RT, already after 3-5 days of food-based nutritional care in hospital patients at nutritional risk. Furthermore, energy and protein intake and balance was found to be positively correlated to intake from specific meals and food items typically used in the intervention group, and improvement in HGS and RT.

The food-sensory-quality-based nutritional care in the intervention group compared to the control group involved an 18% and 14% higher coverage of energy and protein requirements, respectively, from normal food. This was related to a higher intake from lunch and snack meals, the 'super diet', desserts, and 'marzipan, candy, and nuts' in the intervention group. Intake from snacks; 'marzipan, candy, and nuts'; ice cream; and cream was positively correlated with energy and/or protein balance, whereas intake from 'juice, and soft drinks' was negatively correlated. Overall energy and protein intake was significantly higher as a result of the food-sensory-quality-based nutritional care in the intervention group compared to the control group. These results are consistent with previous studies showing that between-meal snacks and enriched, nutrient dense foods can significantly improve energy and protein intake.[27,32,33] Also, a Danish study[34] in three different wards considered to be most representative of the hospital patients, but regardless of nutritional risk status, found a similar positive association between intake of snacks and energy balance. Furthermore, a study by Kondrup et al.[16] found that the nurses were unaware of the importance of snacks, which might have related to the lower intake from snacks in the control group.

The essence of the food-sensory-quality-based nutritional care in the intervention group was to provide appropriate foods as per patients' individualised food sensory needs and motivation to eat.[17,18] Testing of such multivariate interactions was however limited by the sample size of the study. Although some specific food items used in the nutritional care intervention were not associated to energy and protein balance in a general sense, they contributed substantially to energy and protein

intake in individual patients. For example, as high as 39-60% of protein requirements were covered respectively by yoghurt, milk and cream, protein powder and oral nutritional supplements in ascending order.

Change in physiological function during the study period, as assessed by HGS and RT, was not significantly different between the study groups. This is perhaps not surprising considering that the sample size calculation for HGS was based on a difference in energy intake of 2554 kJ, which was almost double the difference in intake of 1288 kJ/day between the study groups. According to a previous literature analysis of trials testing artificial nutrition,[20] an effect on outcome was elicited from almost a doubling in mean intake in the intervention group compared to the control group (i.e., 84 kJ/kg *vs.* 155 kJ/kg). The sample size calculation for energy intake in this study was based on a difference of 1831 kJ/day that was demonstrated by Starke et al.[8] However, energy and protein intake of the intervention group of Starke et al.[8] (i.e., mean ± SD, 6492 ± 1425 kJ, 65.4 ± 16.4 g protein) was comparable to intake of the control group in the current study.

The study by Johansen et al.[19] is the most comparable to the current study since it was conducted in the same hospital and two other Danish hospitals and used similar inclusion criteria and nutritional assessment methods. Mean energy and protein balance in the control group of the current study was 9% and 16% higher than the control group of Johansen et al.[19] This could perhaps relate to the fact that the control group in the current study received general nutritional advice in contrast to the control group in Johansen et al.[19] In regards to the intervention groups, energy and protein balance was 12% and 13% higher, respectively in the present study compared to Johansen et al.[19] The main difference between the nutritional care interventions between the two studies was the focus on food sensory quality in the current study. Furthermore, a nurse and a clinical dietitian provided the nutritional care in the study by Johansen et al.,[19] whereas MSc clinical nutrition and dietitian students directed by JMS, provided the nutritional care in the current study. Therefore, a food-sensory-quality-based approach to nutritional care, as used in this study, appears to be successful at promoting intake in patients at nutritional risk.

HGS improved in both the intervention group and control group, which was significant already after 3-5 days. These results are consistent with those of Christie et al.[4] who found a 12% improvement in HGS after 4 days of parenteral nutritional therapy compared to improvements of 6% in the intervention group and 5% in the control group after 3-5 days of food-based nutritional care in the current study. Even though baseline HGS of the patients in the study by Christie et al.[4] (mean ± SD 26 ± 4 kg) was comparable to the current study, it was likely more compromised since the patients were younger (30 ± 12 years) and were included based on a need for parenteral nutrition. Also, energy and protein intake from parenteral nutrition (9145 ± 832 kJ and 85 ± 8 g protein) was higher. These differences likely contributed to the greater improvements in HGS demonstrated by Christie et al.[4] It is viewed unlikely that these improvements are due to a training effect considering the excellent test-retest reliability of HGS.[35] Also, Christie et al.[4] found rapid improvements in involuntary muscle function tests, which mirrored the improvement in HGS.

As with HGS, RT speed improved and errors of the RT test decreased in both study groups. Improvement in RT appeared more prominent in the control group at the different time points. However, this should be interpreted with caution considering the higher prevalence of missing baseline RT in the intervention group. Improvement in RT was positively correlated to energy and protein balance at 9-11days, which was visible later than for HGS, perhaps due to the greater loss to follow-up and missing baseline values. A study on another Go/No-Go RT test found strong test-retest reliability for RT speed, whereas errors had the potential for a training effect.[36] The rapid improvement found in physiological function (i.e., HGS and RT) could be related to changes in cellular function and metabolism (e.g., membrane potential).[37]

In contrast to the current study, the pilot study[31] did not show a significant improvement in HGS or RT in hospital patients at nutritional risk (N=49) despite mean energy and protein balance comparable to the intervention group in the current study. Baseline HGS (mean ± SD 30 ± 12 kg) was however higher in the pilot study,[31] which could have influenced the lack of effect seen for HGS. Also, a significant positive correlation between energy and protein balance and HGS was found in the pilot study,[31] but was not found in the current study. This could have related to the fact that patients in the current study had lower food intake the week prior to the study (i.e., higher NRS-2002 intake scores). Also, more patients in the current study compared to the pilot study (i.e., 4% in the pilot study *vs.* 19% in the current study) had energy balance <75%. As such, patients in the current study showed improvements in HGS at a greater range of energy balance levels, which likely resulted in a poorer correlation with energy balance than found in the pilot study.

Also, a simple RT test was used in the pilot study,[31] but it was not found to be positively correlated to energy or protein balance, However, the Go/No-Go RT test, which is a complex RT test, was used in the current study instead since it has been found to be sensitive to nutritional interventions in healthy subjects.[10,11] Go-No-Go RT has also been found to be related more so to cognitive function than simple RT.[9]

Body weight did not change significantly during the study period and investigation of specific time points only found significant decreases in weight at 6-8 and 9-11 days. This is likely related to developments in hydration status, which affected about a half of the patients, and was found to be significantly related to changes in body weight. Christie et al.[4] also investigated development in body weight and total body protein, which only improved during recovery, following 14 days of parenteral nutrition therapy in hospital. Johansen et al.,[19] also found no change in weight during hospitalisation. In contrast, Starke et al.[8] found a significant decrease in weight in their control group, but presence of oedema was not reported. As with weight, the BIA results did not change significantly during the study period, but is also very susceptible to changes in hydration status.[38]

Similar to the results by Johansen et al.,[19] the present study did not find any convincing effect on quality of life, as assessed by SF-36. Studies by Starke et al.[8] and Beattie et al.[39] found significant improvements in SF-36 scores from nutritional care in more homogenous patient populations and with higher follow-up response rates of SF-36 of 79% and 100%, respectively, compared to 60% and 52% in the study by Johansen et al.[19] and the current study, respectively. Although SF-36 did not demonstrate a clear effect on quality of life, HGS and RT have been found to be valid measures of quality of life[9,40] and appear to be more sensitive to short-term nutritional care in hospital according to the current study. When comparing change in SF-36 to food intake, change in role-emotional and mental health was found to be positively correlated to protein and energy intake. A study in elderly patients by Paquet et al.[41] also previously found direct and indirect effects of emotions on food intake at meals.

Rate of complications and LOS was not different between the intervention group and control group in our study. However, significantly more patients in the intervention group than in the control group were discharged to home. These results should be interpreted with caution since our study was not powered to show an effect on these outcome variables and because discharge to home was not found to be related to energy or protein balance or intake.

The current study was unfortunately limited by the high rate of loss to follow-up for some outcome variable, including SF-36, RT and BIA, as well as the different number of measurement sessions and length of follow-up periods in hospital due to varying LOS. Another limitation was that the nursing staff were not blinded to the nutritional care intervention and perhaps learned from the food-sensory-quality-based approach of the intervention group. The nurses were also aware of the previous food sensory quality studies,[17,18] which were conducted on the same units. As a result, the control group could have benefited indirectly from the nutritional care intervention, decreasing the

likelihood to see any difference between groups. Furthermore, the hospital menus were not developed in accordance with the food-sensory-quality-based approach used in the study. Further development of products food and meals to address to the varying food sensory needs of patients at nutritional risk could perhaps have helped to improve the efficacy of the nutritional care intervention.

In conclusion, this study demonstrated benefits from individualised, food-sensory-quality-based nutritional care on improved energy and protein intake in hospital patients at nutritional risk compared to usual nutritional care and advice. Physiological function, measured by HGS and RT, improved rapidly with significant improvements already after a few days of nutritional care within both the intervention group and control group, but no significant difference was detectable between study groups.

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FRAMEWORK FOR DEVELOPING FUNCTIONAL FOODS FOR PATIENTS AT NUTRITIONAL RISK

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